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The currents of the upper air are invisible, and they leave behind them no landmarks to record their track. We know not whence they come or whither they go. We have a certain rapidly increasing acquaintance with the laws of general atmospheric motion, but of the origin and limits, the beginning and end of that motion, as it manifests itself at any particular time and place, we know nothing. We cannot say where or when the vapor, exhaled today from the lake on which we float, will be condensed and fall; whether it will waste itself on a barren desert, refresh upland pastures, descend in snow on Alpine heights, or contribute to swell a distant torrent which shall lay waste square miles of fertile corn land; nor do we know whether the rain which feeds our brooklets is due to the transpiration from a neighboring forest or to the evaporation from a far-off sea.[1]

IN THESE words, one of the most literary of the geographers of the nineteenth century summarized the state of existing knowledge concerning the hydrologic cycle. The source of the moisture which appears as precipitation in an area and the ultimate disposition of that portion which is re-evaporated has been a subject of scientific concern for centuries. This question is not one of academic interest alone but has an important bearing on a number of beliefs which have exerted a powerful influence on scientific as well as popular thinking. Marsh,[2] in referring to the belief that vegetation and precipitation are reciprocally necessary to each other, quotes the following:

> Afric's barren sand,
> Where nought can grow, because it raineth not,
> And where no rain can fall to bless the land,
> Because nought grows there.

The idea that vegetation influences rainfall, in fact determines its amount and distribution, is so firmly rooted that it has been the basis of many action programs. In our country the Timber Culture Act of 1873 was passed in the belief that if the western farmers were induced to plant trees rainfall would be increased sufficiently to eliminate the climatic hazards to agriculture.[3] This belief still persists among some of these western farmers. During the current drought more than one has blamed his difficulties on his own failure to plant trees.

The same idea has reappeared in many forms. Aughey,[4] writing of Nebraska in 1880, credited the increased rainfall then being experienced to the spread of cultivation. He said—

> It is the great increase in absorptive power of the soil, wrought by cultivation, that has caused, and continues to cause an increasing rainfall in the State * * * . After the soil is "broken", a rain as it falls is absorbed by the soil like a huge sponge. The soil gives this absorbed moisture slowly back to the atmosphere by evaporation. Thus year by year as cultivation of the soil is extended, more of the rain that falls is absorbed and retained to be given off by evaporation or to produce springs. This, of course, must give increasing moisture and rainfall.

A long drought period setting in shortly thereafter, while Nebraska was still being settled, demonstrated the fallacy of Aughey's hypothesis, but apparently failed to lead to a critical examination of its premises. In a publication released this year, Clements,[5] in describing an investigation to determine the relative moisture contributions to the atmosphere from native grasslands and field crops as sources of moisture for local rainfall, conducted by Weaver and himself in 1923, says:

> The outcome demonstrated that there was no material difference in transpiration and evaporation from the two types of cover, and hence that cultivation could have had no favorable influence upon precipitation.

[1] Marsh, G. P. Man and Nature; or, Physical Geography as Modified by Human Action. New York, 1864. p. 183.

[2] Marsh, G. P. Man and Nature; or, Physical Geography as Modified by Human Action. New York, 1864. p. 182.

[3] Thornthwaite, C. W. The Great Plains. *In* Migration and Economic Opportunity. Philadelphia, 1936. p. 209.

[4] Aughey, S. Sketches of the Physical Geography and Geology of Nebraska. Omaha, Nebr. 1880. pp. 44-45.

[5] Clements, F. E., and Chaney, R. W. Environment and Life in the Great Plains. Washington, D. C. 1937. (Carnegie Inst. Supp. Pub. 24.) p. 41.

By C. W. Thornthwaite, Head, Section of Climatic and Physiographic Research, Division of Research, Soil Conservation Service, Washington, D. C.

THE HYDROLOGIC CYCLE RE-EXAMINED

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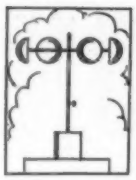


There is no question that various types of vegetation and land use do contribute varying amounts of water to the atmosphere. A great mass of experimental evidence demonstrates this, but there is no similar demonstration that the moisture added to the atmosphere in this way is reprecipitated later in the same area. This is a matter which can be settled only when the sources of moisture for precipitation are known.

It is true, as Marsh said, that the currents of the upper air are invisible and that they leave behind them no landmarks to record their track. Of course, there are well-known exceptions, such as the transport around the world of volcanic dust from the explosion of Krakatoa in 1883 and the movement of dust from the Sahara to southern and central Europe. In recent years dust from the Great Plains reaching the Eastern States and the Atlantic has given further evidence on the direction and rate of air flow. However, such casual observations of dust in the atmosphere give only meager information about the movement of air currents and the transport of water vapor.

To answer the puzzling question about the source of moisture for precipitation, hydrologists have sought other evidence. Patient observation had indicated that the amount of water precipitated upon the lands exceeds that which runs off. Still the water level of the sea has not been lowered a measurable amount in historic time. Therefore, it is argued, the sea must contribute to continental precipitation only that portion which later runs off on the surface and underground; the remaining precipitation must be due to continental evaporation, and this being true, any means of increasing continental evaporation will result in increased rainfall.

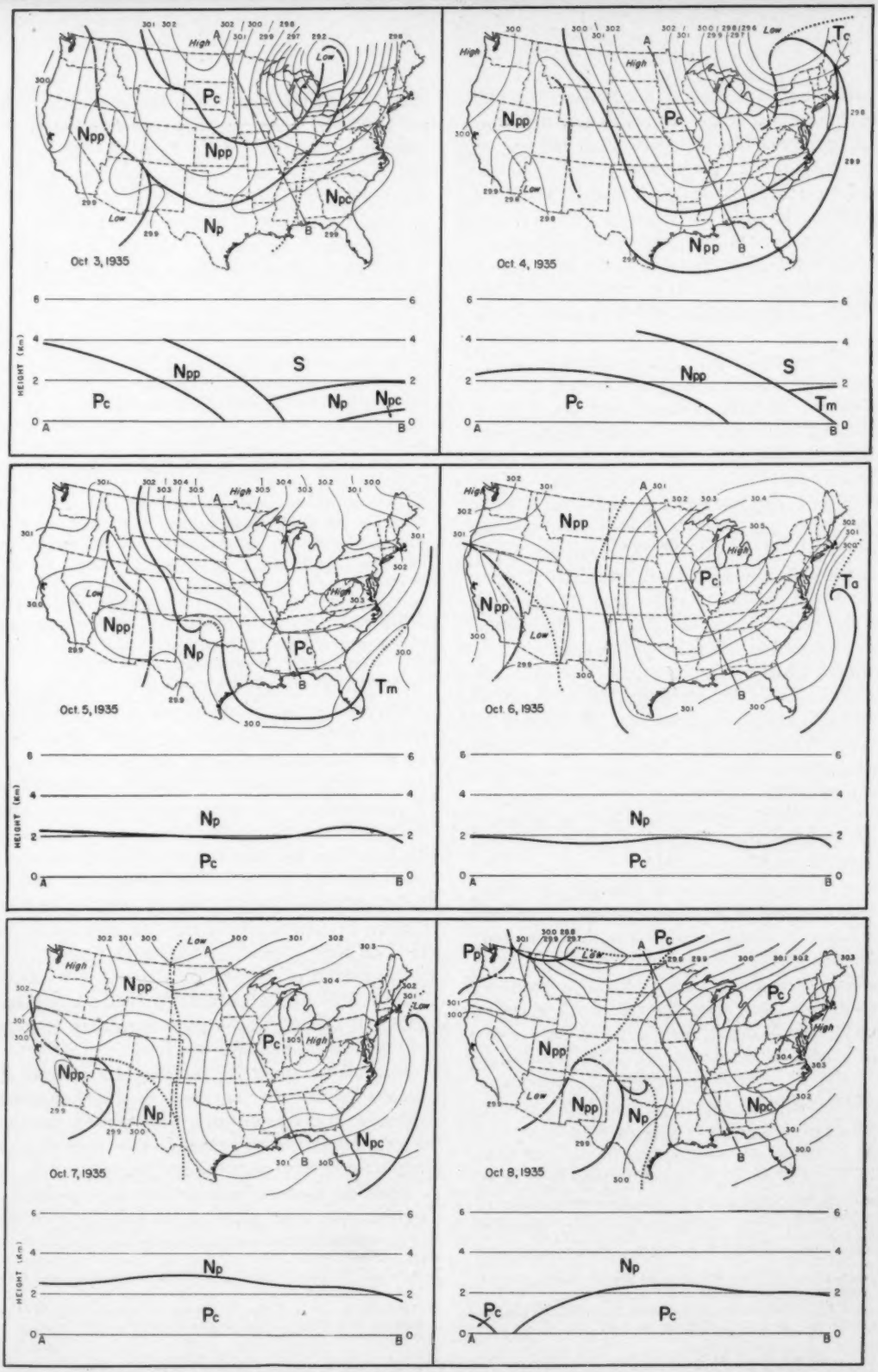
It is clear that a constant sea level demonstrates a hydrologic balance between the amount of moisture received from the sea by the land and that returned to the sea. It is also clear since water does not run up hill that moisture reaches the continents from the oceans only through the atmosphere. But there is no indication that water returns to the ocean only by flowing downhill as surface run-off. Gravity moves water in one direction only from land to sea. But gravity does not have the same control over the movement of atmospheric currents, and it is not unreasonable to suspect that if water vapor is transferred from the ocean to the land by the wind, it would also be transferred from land to ocean by the same means.

Records of run-off from lands to oceans and of precipitation on lands are considered to be sufficiently reliable to indicate their relative proportions. It is estimated that for the United States less than 30 percent of the moisture which falls as precipitation runs off the land and reaches the ocean. It may be argued that the continental moisture is transferred to the ocean only as run-off, and that since the ocean levels are constant less than 30 percent of the precipitation has a marine origin and the remainder represents reprecipitation from continental evaporation. It may be argued equally well that all of the precipitation is of marine origin, and that, since less than 30 percent runs off in streams and as underground flow, more than 70 percent must return to the ocean as water vapor. Thus, the disparity between the amount of water which falls upon a continent as rain and that which runs off from it to the ocean is in no sense an indication of the source of the precipitated moisture. We must seek elsewhere for the answer to this puzzling question. A provisional answer comes from a most unexpected source:

For several years a diligent group of meteorologists in Norway, using the meager data at their disposal have been furthering a revolutionary meteorologic idea. They maintain that the atmospheric circulation of the middle latitudes is due to the interaction of huge masses of air which are developed over so-called source regions and have uniform physical properties characteristic of the source regions.

Early each morning for the last 2 years, airplanes have taken off from the airport of a number of American and Canadian cities and have ascended to heights of 3 or 4 miles carrying delicate meteorological instruments for determining the characteristics of the upper air. In this way it has been possible to determine the temperature, pressure, and moisture content at various levels aloft. In addition, pilot balloon runs determine the velocity and direction of movement of the air. These observations verify the conclusions which had previously been made on the basis of occasional and unrelated kite soundings of the upper air in our country and prove the correctness of the concept of air masses.

It has been found that huge masses of air of great depth develop uniform physical properties over a



Invasion of Polar Continental air October 3-8, 1935. The 8 a. m. position of surface fronts. Cross sections from Canadian border to Gulf of Mexico show changing upper air relations of the air masses. KEY: Pp, Polar Pacific air; Pc, Polar Continental air; S, Superior air; Ta, Tropical Atlantic air; Tm, Tropical Maritime air; N, transitional type; solid line, cold front; dotted line, warm front; dash line, clouded front.

number of source regions in North America. The outward movement of the air from these centers, and the interaction of different types of air masses, are chiefly responsible for the weather of the continent. Several types of air masses are involved. The Polar Continental air, which is uniformly cold, dry, and heavy, forms over the vast Arctic tundra of northern Canada. The north Pacific Ocean is the source region for the characteristically cold and moist Polar Pacific air. Both masses generally move in a southeasterly direction across the continent and may encounter northward-moving Tropical Atlantic air masses, which are warm, very moist, and light. Tropical Atlantic air develops its characteristics over the Gulf of Mexico and the region lying between Bermuda and the Bahamas. The other types of air masses, not being essential to this discussion, are not described.

When the Polar Continental air pushes out from its source region and flows southward and eastward across Canada and into the United States and thence south and southeastward, it usually collides all along its route with the lighter and moister air advancing from the Gulf or from the Atlantic, which being lighter, is forced to ascend and yield moisture by precipitation. Most of the rainfall of eastern North America is caused by the interaction of these air masses. The storms which produced the floods of the Ohio and Mississippi during January of this year were caused by the ascension of Tropical Atlantic air over Polar Continental. The line of contact or boundary between the air bodies became temporarily stationary over the Ohio Valley, resulting in heavy rainfall as long as such conditions prevailed.[6] [7]

Observations of the upper air were initiated chiefly as an aid to improved weather forecasting. They have in addition, however, supplied a method for determining the sources of moisture. Although air is invisible, the air masses possess certain properties by which it is possible to trace their movements across the country. The Weather Bureau has recently established an Air Mass Division, where the "soundings" are analyzed and the pecularities of temperature, specific humidity, and pressure of each air mass are determined and where daily maps showing the position of the various air masses and their "fronts" are made.

The upper air observations make it possible to determine daily the total amount of water vapor in the air at the stations where soundings are made. Knowing the direction and rate of movement of the various air masses it is possible to determine which air masses lose and which gain moisture as they cross the country.

Benjamin Holzman,[8] of the Division of Research, Soil Conservation Service, has utilized the available upper air soundings in developing a method for locating the sources of moisture for precipitation. He has summarized a portion of his study in the Transactions of the American Geophysical Union as follows:[9]

> Polar air masses advancing equatorward absorb moisture by evaporation, become heated, and are eventually transformed into warm, moist, tropical air masses. Tropical air masses on the other hand, traveling poleward, precipitate most of their moisture, become cooled, and are ultimately transformed into cold, dry, polar air masses. This air mass cycle which is manifestly an expression of the general circulation of the atmosphere is closely associated with the balance of water over continental areas or, as is better known, the hydrologic cycle. In the cycle of air mass transformation it is apparent that moist, tropical maritime air bodies must rid themselves of their high water vapor content before they can ultimately be modified into polar air masses, and similarly polar air masses must gain in moisture before they can properly be transformed into tropical maritime air masses. Thus, in the alternating inundations of extensive bodies of air of different origin can be distinguished two principal classes, those that are losing their moisture and consequently contribute the major portion of precipitation on the earth and those that are absorbing moisture and constitute the greatest robbers of moisture from continental areas.

Mr. Holzman determined the gain or loss of moisture during the passage of a number of carefully selected air masses across the country. He also used the average values of properties of Polar Continental and Tropical Atlantic air masses and computed the gain of moisture to the first and loss from the second. He found the total water content of Polar Continental air at Ellendale, N. Dak., to be the equivalent of 0.44 inches of rainfall and at Pensacola, Fla., to be 0.97 inches. In traveling from the Canadian border to the Gulf these air masses absorbed 0.53 inches. The water content of Tropical Atlantic air at Pensacola was equivalent to 1.67 inches of rainfall and at Ellendale 1.01 inches. The journey northward resulted in a net loss of 0.66 inches of water.

Mr. Holzman recognized that the polar air gained 20 percent less moisture than the tropical air lost. This value, he cautiously suggests, would indicate the percentage of precipitation available for run-off if these two air-mass types were the only ones concerned.

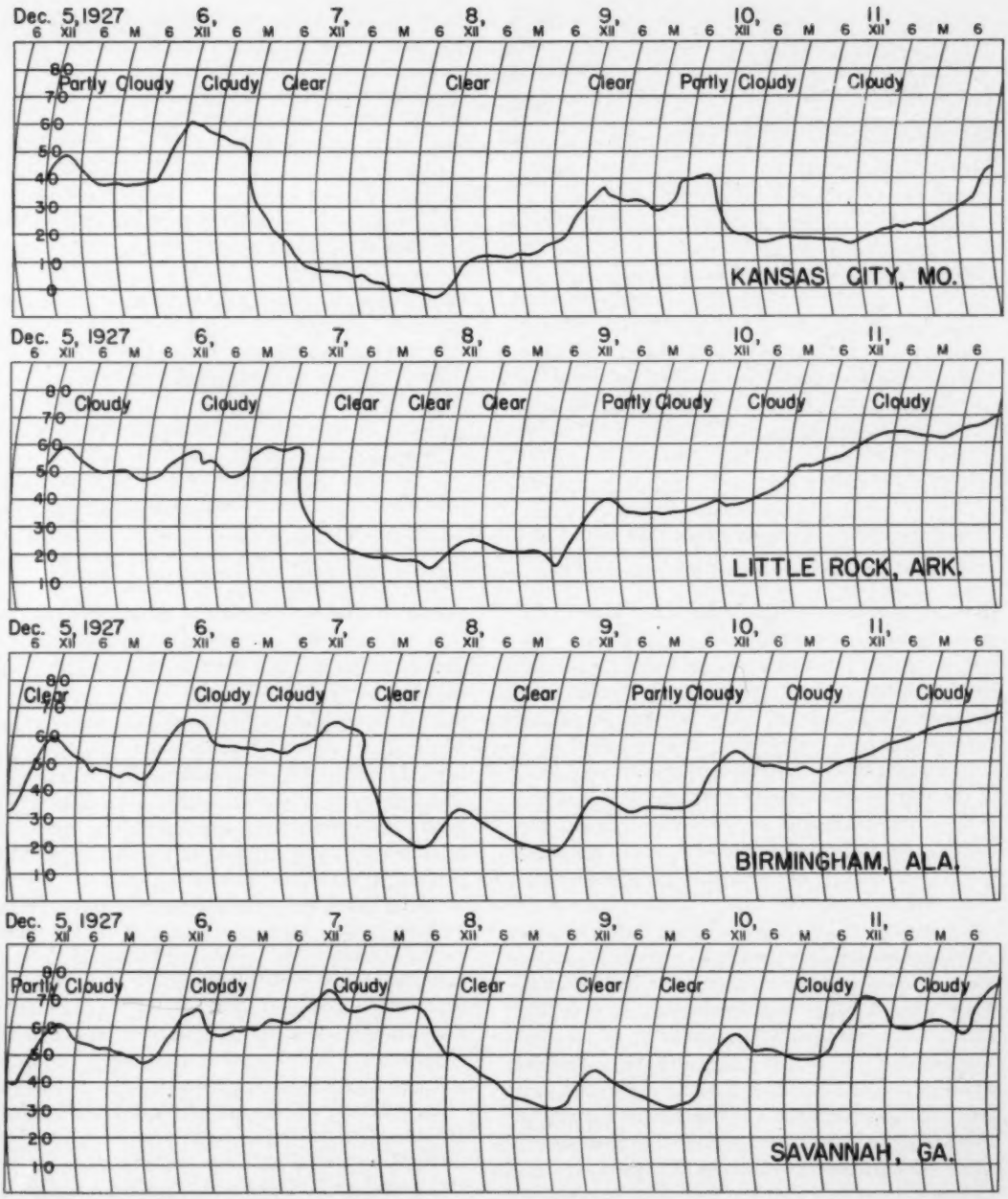
Hydrologists have been inclined to view the hydrologic cycle from below, commencing with run-off. It now appears that we might do well to view it from

[6] Thornthwaite, C. W. Climatic Studies and Canadian-American Relations. Conf. on Canadian-American Aff. Proc. 1937. (In press.)

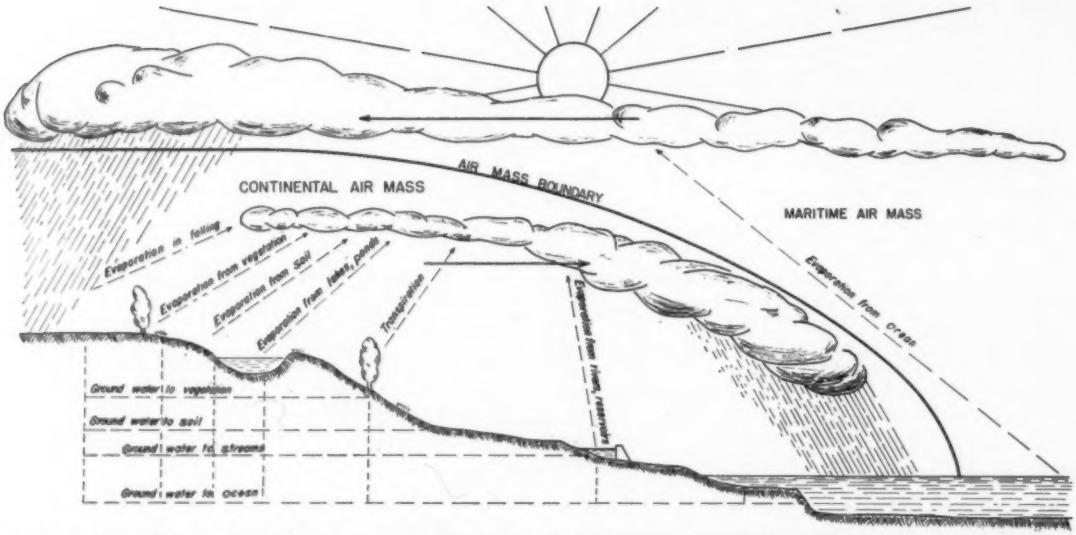
[7] Holzman, B., and Clarke-Hafstad, K. Changes in Atmospheric Circulation Result in Floods. Soil Conserv. 2 (11): 254–255, 266. 1937.

[8] Holzman, B. Sources of Moisture for Precipitation for the United States. U. S. Dept. Agr. Tech. Bull. 589.

[9] Holzman, B. Use of Aerological Soundings in Determining the Source of Moisture for Precipitation. Amer. Geophys. Union Proc. 1937. (In press.)


Dec. 5, 1927
6, 7, 8, 9, 10, 11,
Partly Cloudy Cloudy Clear Clear Clear Partly Cloudy Cloudy
KANSAS CITY, MO.
Cloudy Cloudy Clear Clear Clear Partly Cloudy Cloudy Cloudy
LITTLE ROCK, ARK.
Clear Cloudy Cloudy Clear Clear Partly Cloudy Cloudy Cloudy
BIRMINGHAM, ALA.
Partly Cloudy Cloudy Cloudy Clear Clear Clear Cloudy Cloudy
SAVANNAH, GA.

When a Polar Continental air mass comes out of the north and flows across the United States, it leaves an unmistakable record on every thermograph chart. The charts reproduced here show that the "front" passed Kansas City at 11 p. m., December 6; Little Rock at 9 a. m., December 7; Birmingham at 8 p. m. on the 7th; and Savannah at 7 a. m. on the 8th. The temperature at Kansas City dropped continuously from 53° above to 4° below zero Fahrenheit during the 33 hours following the frontal passage. At Savannah the temperature drop was from 66° F. to 30° F. in 26 consecutive hours. Although the air mass was modified at Savannah, it was still unmistakable.



This version of the hydrologic cycle calls special attention to the part played by maritime and continental air masses in the transport of moisture to and from the continent. It indicates that some moisture reaches the sea as surface run-off and underground flow, and that some returns in the continental air masses.

above, commencing with atmospheric circulation. By so doing, we observe two types of air masses: The first, warm and moist, being cooled and consequently losing moisture by condensation and precipitation; the second, cold and dry, being warmed and gaining moisture through evaporation. The run-off from a large drainage basin can be thought of as an expression of the relative effectiveness of these air-mass types. If the moist masses lose more moisture than the dry masses gain, there will be run-off. If, on the other hand, absorption by dry masses equals precipitation, there will be no run-off.

The consideration of the hydrologic cycle from the standpoint of air masses reveals an important omission from all existing diagrams illustrating its operation. They indicate that moisture evaporates from the oceans and is transported by the wind to the continents where it is precipitated. From there the course of the water is traced. Some is re-evaporated into the air; some returns to the oceans by way of rivers and underground waterflow; but nowhere is there recognition of the fact that any portion of the moisture evaporated from the land is transported by the wind back to the oceans. The diagram which accompanies this article does not cover all the details of the water cycle, but it does indicate the important phases. Moisture evaporated from the land may be reprecipitated over land areas; but since this source does not compare with the oceanic source, it is not shown on the diagram. Likewise the maritime air masses do absorb some of the moisture evaporated from the land, but for the sake of simplicity this is omitted. The fact that the moisture content of the maritime air masses eventually diminishes as they proceed across the land indicates that they are not receiving any significant quantities of water from the land. However, this is a question still to be examined. The records of a few automatic evaporation pans should be analyzed with reference to the succession of air masses. In this way we can determine what happens to evaporated moisture.

The consideration of the bearing of air masses on the hydrologic cycle suggests the need of further fundamental research. The preliminary findings of Holzman indicate that the principal source of moisture for precipitation on the land is the ocean, and that continental evaporation as a source of local precipitation is relatively insignificant. They suggest that changes in vegetation cover or land use, although not denying an influence on evaporation, will not increase or decrease precipitation in any measurable amount.

Polar Continental air bodies, being heavy, flow along the surface and, except where greatly modified, are easy to trace. A characteristic manifestation of the passage of a polar front is the abrupt, even precipitous, drop in temperature and rapid rise in pressure. The rate of movement varies, but seldom does it take more than 3 days for a front to advance from North Dakota to the Gulf or the South Atlantic coast.[10]

[10] Thornthwaite, C. W. The Polar Front in the Interpretation and Prediction of Oklahoma Weather. Proc. Okla. Acad. Sci. Vol. 9, 1929. pp. 93–99.

Assuming that the polar air requires 3 days for its passage and that it absorbs the average amount of water, 0.53 inches, as indicated above, the actual water removal from an area the size of the Mississippi drainage basin become tremendous. It reaches the astonishing rate of 5,909,000 cubic feet per second, which is more than nine times the average discharge of the Mississippi River. During the Polar Continental invasion of October 3 to 5, 1935, the total moisture in the lower 1,500 meters at Fargo was equivalent on the 3d to 0.12 inches of rainfall. Two days later at Pensacola the same air column had a moisture content equivalent to 0.38 inches. This air mass absorbed 0.26 inches of moisture in approximately 48 hours, which, if representative of the entire Mississippi Basin, would represent a discharge of 4,348,000 cubic feet per second, still more than seven times the average discharge of the Mississippi River, and nearly one and one-half times the maximum flood flow of record.

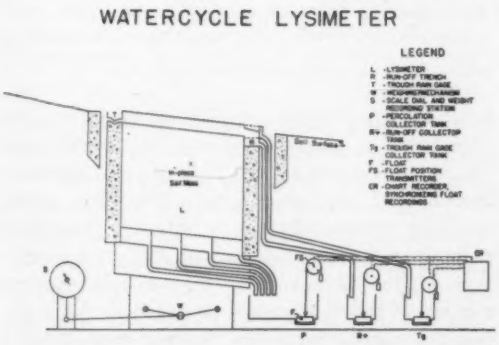
The Polar Continental air masses which flow from the Canadian Prairies southward and southeastward across the continent to the Gulf and to the Atlantic are in effect great invisible rivers transporting water from the land to the sea at rates apparently vastly greater than those of the surface drainage.

This suggests a novel method of flood control. It would seem that any method of soil conservation or of forestry which would retard the run-off in the headwaters area of a drainage basin would increase the evaporation opportunity of the water. In this way more of the water would be diverted from the surface streams into these great invisible atmospheric streams. Any technique which would stimulate additional evaporation of excessive rainfall from the land into these atmospheric streams, there to be conducted harmlessly back to the seas, would serve as an important and supplemental flood-protection measure.

It should be understood that the foregoing flood-control suggestions still lie within the realm of theory. It is clear that if they were to work they would have tremendous possibilities. For that reason, it is hoped that this article will stimulate open-minded discussion and argument as well as further investigation from which should come greater appreciation of the interdependence of meteorology and hydrology, if nothing more.

In-Place Lysimeters Near Coshocton, Ohio

By Walter Urban Garstka [1]



A CONSTRUCTION program, somewhat mystifying to a few of the old residents, has been going forward during the past year and a half near Coshocton, Ohio. A number of batteries of lysimeters are being built upon the North Appalachian experimental watershed, a project of the section of the watershed and hydrologic studies of the Research Division of the Soil Conservation Service.

A lysimeter may be defined as a structure containing a mass of soils designed to permit the measurement of the amount of water percolating through the soil mass. Three distinct types of lysimeters have been used—the transported, the in-place, and the so-called Russian type. In the transported type, the lysimeter unit is constructed and then filled with soil. The in-place type of lysimeter is built in such a way as to contain an undisturbed soil mass, with its horizons intact. The Russian type of lysimeter consists of a shallow pan inserted at desired depths under undisturbed soil horizons.

The installation, over 150 years ago, of the first lysimeters is commonly credited to the English scientist, Dalton (recognized as the father of the atomic theory), in his effort to determine the amount of precipitation which percolates through the soil. The Coshocton lysimeters have been designed primarily for water cycle studies, and are of the in-place type.

[1] In Charge, Soil and Land Use Unit, Watershed and Hydrologic Section, Research Division, Soil Conservation Service, Washington, D. C.

Lysimeter box shown sunk about half-way down; over 10 tons of sand were necessary to overcome friction between soil mass and asphalt-treated box sidewalls.

The lysimeters are built in groups of three. The horizontal projectional dimensions of each unit are 6.22 feet by 14 feet; the depth is 8 feet. The projectional surface of each unit is 2 milacres. The lysimeters have been designed and built to study the amount and rate relationships between rainfall, run-off and percolation, and to evaluate the magnitude of evapo-transpirational water loss.

A schematic diagram depicting the principal features of the lysimeter is shown with this article. In order to study the relationship between amounts, intensities, and duration of intensities of rainfall, run-off and percolation, the lysimeters are built to contain an undisturbed block of soil comprising the complete soil profile and including about 2 feet of the parent rock material. They are provided with catchment tanks to collect the rainfall, run-off, and percolation waters. The catchment tanks are equipped with mechanisms which allow central recording upon a clock-driven chart of the amount and intensities of the water piped to them. An automatically recording weighing device has been developed expressly for use in this study. This device is capable of recording automatically, at stated intervals, the time of the weighing and the total weight of the 130,000-pound lysimeter and soil mass within 5 pounds. This is less than one one-hundredth of an inch of precipitation over the area of the lysimeter. The record of the weight of the lysimeter at definite times will serve as a check upon the observed precipitation, run-off, and percolation data. It will give data upon evapo-transpirational water loss adaptable to interpretation in terms of surface area.

Three lysimeter units have been sunk into place. An early stage in the construction of the collector tunnel is shown in the foreground.

This lysimeter installation, based upon a detailed study of preceding lysimeter installations, is the result of much thought and effort on the part of over 15 individuals, comprising members of the Soil Conservation Service, the Ohio Agricultural Experiment Station, and specialists in delicate large-capacity weighing devices. Actual construction was made possible for the most part through the active cooperation of the Works Progress Administration. A number of technical papers dealing with the design and construction procedure of these in-place lysimeters are now being prepared.

An early stage in the construction of an in-place watercycle lysimeter. Reinforcing steel is being placed in forms in preparation for casting of the concrete box.

More than 40 percent of the soil wealth is contained in the top 6 inches of soil.

The Romans noted the folly of growing the same crops on the same land for several consecutive years.

PROTECTING BOTTOMLANDS FROM EROSIONAL DEBRIS: A CASE HISTORY

By Carl B. Brown [1]

IN many parts of the United States cultivation of fertile bottomlands and gentle alluvial slopes is being menaced by erosional debris swept down in storm run-off from adjacent denuded mountains and steeply sloping uplands. The damage resulting when debris-laden torrents gush out upon flood plains, with sudden dissipation of velocity and deposition of debris load, is usually twofold: (1) The natural and artificial drainageways on the alluvial slopes and bottomlands are clogged with debris, and subsequent flooding of fields by storm run-off occurs; groundwater levels rise, and land becomes waterlogged. (2) Assorted and usually coarser erosional debris derived from subsoils and spread over the bottomland impairs its fertility and often destroys its productive value.

Damage of this type is usually local, restricted at first to the immediate debouchure of tributaries on a flood plain or alluvial slope, but spreading progressively as the process continues. It should be distinguished from similar widespread sanding and aggradation produced during floods by alluvial streams on their own flood plains with sediment often transported from far distant headwater areas. For the latter phenomenon, no immediately effective cure is yet in sight; extensive soil conservation, changes in land use, and direct flood-plain protection will be required. Protection against local damage from erosional debris is, however, frequently obtainable in a short span of time and may be economically justified. It is, indeed, often a problem of immediate concern because alluvial lands are nearly everywhere notably productive and are rarely subject to the hazards of soil erosion common to most upland areas. Developing optimum methods for this protection is proper work for the Soil Conservation Service.

Elaborate and costly means are sometimes justified on thickly-populated alluvial lands. Debris basins formed by concrete dams have been constructed by the Los Angeles County Flood Control District on the alluvial slopes at the base of the San Gabriel Mountains for protection of suburbs of Los Angeles. But for the protection of ordinary agricultural lands, other and more economical methods must be sought. The first hope, of course, is adequately to protect by soil-conservation measures the watersheds from whence the erosional debris comes. This at once brings forth pertinent economic questions involving costs justified for the protection of both upland and alluvial soils.

THIS article describes one solution of this problem, and lays a partial basis for appraising its merits. It is based on a survey made by the Section of Sedimentation Studies, Division of Research, in June 1937.[2]

Doniphan County, Kans., the State's extreme northeastern county, is bordered on its north and east sides by the Missouri River. Intermittent areas of flood plain along the river are intensively farmed because of their fertile alluvial soils.

One of these areas, comprising 4,300 acres, is in Burr Oak Township, approximately 8 miles northeast of Wathena. The area consists for the most part of river-deposited alluvial soils fringed along the river by sand bars and debris, mapped as River Wash. On the south side the area is bordered by a steep and relatively straight bluff line through which a number of small tributary streams have cut steep and narrow ravines leading from the rolling uplands.

All the soils of this alluvial area are members of the Sarpy series,[3] of which Sarpy clay is most common, with lesser amounts of Sarpy silty clay loam and Sarpy very fine sand loam. The Sarpy silt loam which occurs principally along the bluff line represents an admixture of silt and coarser material from the uplands with clay of the river alluvium.

OF the several tributaries heading in the uplands and flowing onto the alluvial flood plain, Chase Creek is the largest. It has a watershed of 1,011 acres. Old residents report that 40 years ago both this small watershed and the bottomlands were well forested, and that water emerging on the flood plain was usually clear or that its occasional small-silt load was deposited in thin layers over the wooded bottom. Between the time of clearing the watershed and 1920, Chase Creek had built an alluvial fan sloping in all directions from its mouth for an average distance of 1,500 feet. The apex of the fan was 6 feet higher than the outer fringe giving a slope of approximately 22 feet to the mile. Much of the material composing this fan is said to

[1] Associate Geologist, Section of Sedimentation Studies, Division of Research, Soil Conservation Service, Washington, D. C.

[2] Acknowledgment is due to E. M. Flaxman, junior geologist, who, assisted by E. H. Moser, Jr., made a topographic survey of these debris basins and collected additional information on their history.

[3] Knobel, E. W., Davis, R. H., and Higbee, H. W. Soil Survey of Doniphan County, Kans., U. S. Dept. Agr. Bur. Chem. and Soils Series 1927, No. 25.

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have been brought down as the result of a cloudburst in June 1917.

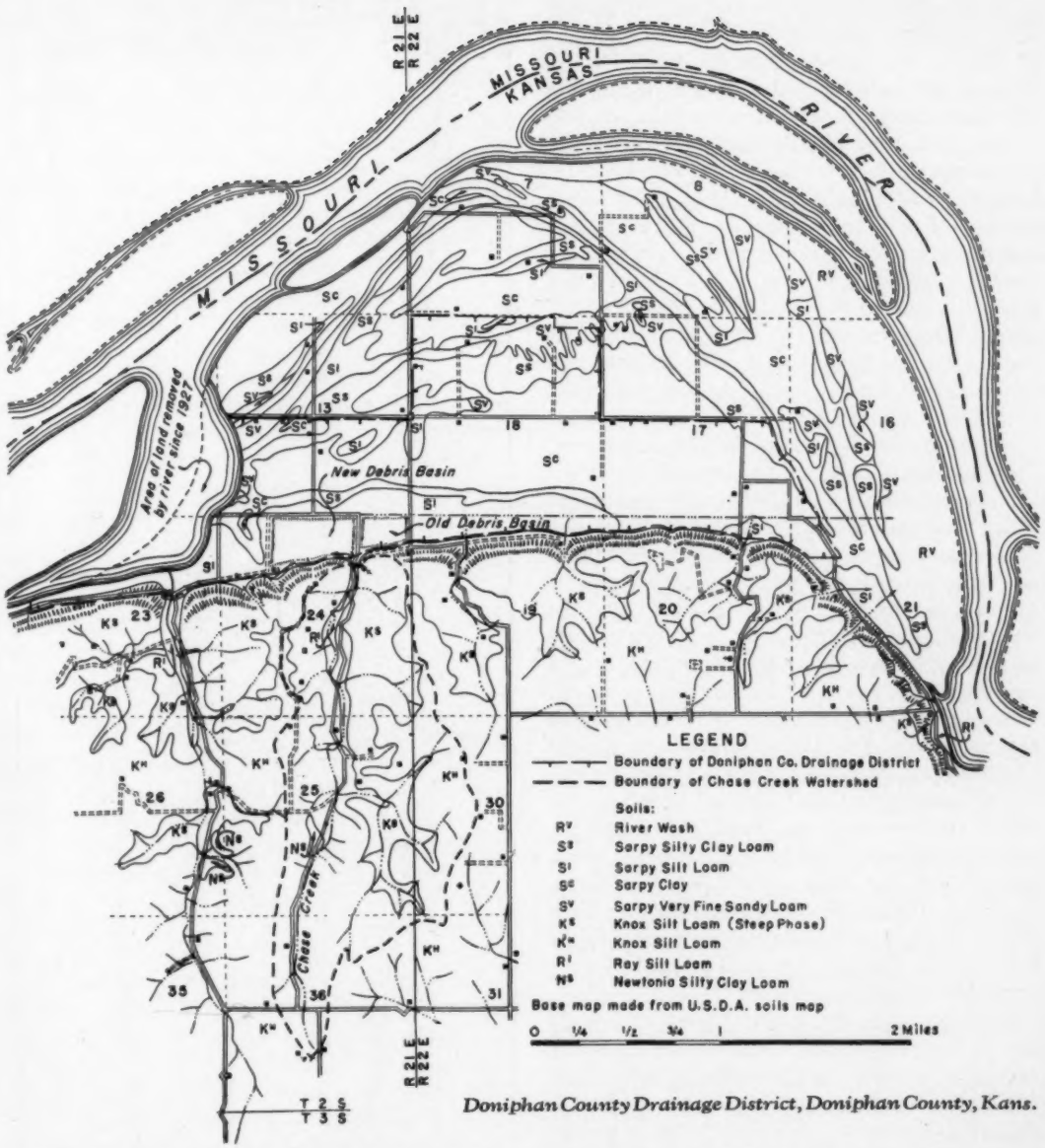
The damage resulting from the storm of June 1917 through flooding of growing crops and spreading erosional debris over them, led farmers in the afflicted portion of the flood plain to organize the Doniphan County Drainage District in 1919, taking in 1,900 acres of bottomland. An engineer was employed to survey the area and make recommendations for control of floodwaters and erosional debris and maintenance of drainage. He recommended the construction of a debris basin or diked-off area adjacent to the bluff line to impound both sediment and floodwater until the latter could drain off quietly into a ditch and be carried directly east 2½ miles to natural sloughs draining into the river.

IN 1920 a contract was entered into between the district and C. F. King for rental of 26.6 acres of his land lying just east of the mouth of Chase Creek (sec. 24, R. 21 E., T. 2 S.). This is indicated as the "old debris basin" in the accompanying map. This land was converted into a basin by an earth dike averaging 6 feet in height. The dike on the north side constituted the inner side of the drainage ditch and a second parallel dike constituted the other side. The ditch was dug about 3 feet below ground surface, the excavated material being used in the construction of the dikes. The ditch, which was 10 feet wide, thus had an effective depth of 9 feet. Beyond the desilting basin, no dikes other than spoil banks were constructed along the ditch. The ditch slopes 4.21 feet per mile to the slough where it terminates. No outlet from the basin was provided and water generally escaped by percolation and evaporation, except occasionally when it overflowed the dikes. Whatever damage occurred from overflow was periodically repaired. The flow of Chase Creek was diverted into the basin by a road embankment built across its original channel.

BY 1930 the original basin had completely filled with sediment and the channel was diverted into a similar basin of 73 acres on the west side of the mouth of Chase Creek. Between the spring of 1920 and the spring of 1930, the original basin was filled to an average depth of 5 feet with sediment derived from the 1,011-acre watershed. The depth varied from 8.2 feet near the entrance of the creek to 2.8 feet in the northeast corner. Within this decade, the sediment deposited amounts up to 135.6 acre-feet, equivalent to a removal of 0.13 foot of topsoil over the entire watershed. To this must be added an unknown quantity of sediment that was carried down the drainage ditch, particularly after the basin was nearly full. The ditch was cleared out for most of its length in 1930, a fact which shows that even the spill-over sediment was too coarse or too abundant to be carried by the waterflow on a grade of more than 4 feet to the mile. The indicated rate of erosion, based on sedimentation in the basin alone, would cause complete removal of the 6-inch topsoil layer (average depth for Knox silt loam) in 35 years or less.

THE contract between the district and Mr. King provided for rental of 26 acres of land at the rate of $25 per acre per year, but allowed him to continue such use of the land as he might choose, subject to flood hazard. Mr. King planted the land almost every year and crop production was extraordinarily high when no floods occurred. His production of corn ran 65 to 80 bushels to the acre when no damage occurred, a record that has been maintained since waterflow was diverted to the new basin. He reports that one year he raised 103 bushels to the acre. These figures compare with an average production of about 40 bushels per acre on adjacent alluvial land. They indicate in a most striking way the plant food values lost from the Chase Creek watershed and laid down on this field. Taking into account crop losses by flooding, Mr. King averaged 25 bushels of corn per acre in the debris basin during the 10-year period. King also derives excellent yields from tomatoes, watermelons, strawberries, and beans on the old silting basin. The more sandy soils in the upper part of the basin are used principally for truck crops and the finer-textured soils in the lower part for corn. There have been no appreciable differences in crop yields over a period of years.

THE new desilting area is not surrounded by a well-defined dike. Instead the water is directed along the edge of the bluff by a low dike about 200 feet in front of it. This abruptly checks the incoming current and causes deposition of coarser materials, temporarily protecting the remainder of the basin. A road to the west, north, and east of this basin is 2 to 3 feet higher than the enclosed land, and the drain on the inside connects with the old drainage ditch and serves as an outlet for surplus water.



Doniphan County Drainage District, Doniphan County, Kans.

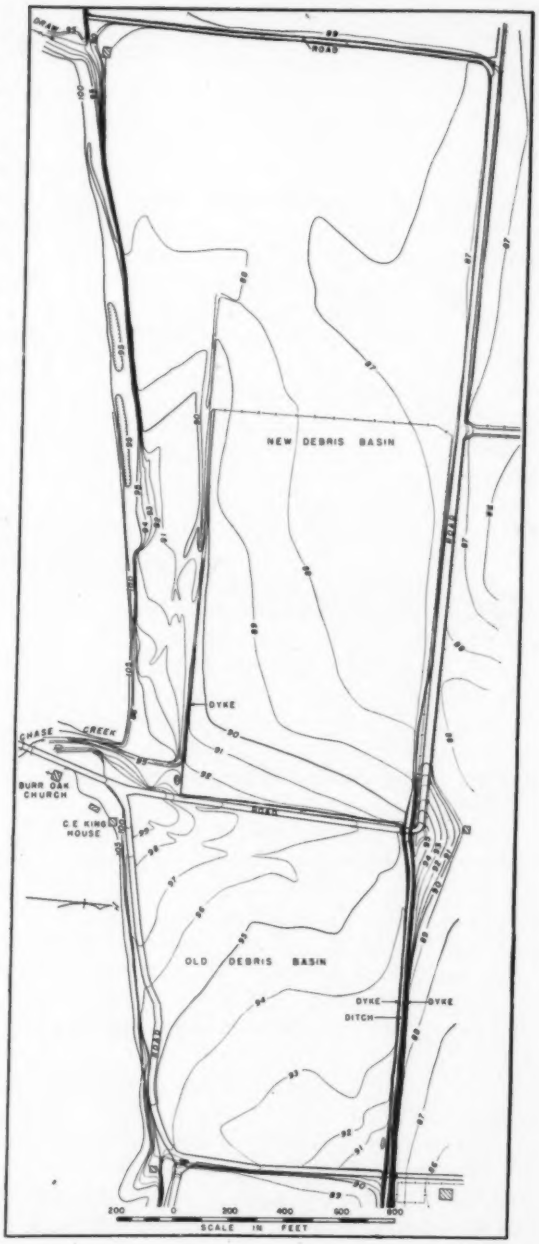
On June 7, 1937, a cloudburst caused a flood which tore out a portion of the low dike where it is buffeted by the direct current from the mouth of the creek. Boulders derived from bed rock were strewn over 1 to 2 acres below the mouth of the creek, and a deposit of medium to coarse sand extended beyond. Most of the sediment, however, was deposited on the western half of the basin. The silt deposits were thick enough to make necessary replanting of the corn crop.

The watershed of Chase Creek is entirely covered by Knox silt loam and its steep phase. More than 90 percent is in cultivation and orchards, woodlands being restricted to the narrow valley of the creek and the steep slopes along the Missouri River bottomlands. The principal crops are raspberries, beans, and other garden truck, with corn, wheat, and rye on the flatter uplands. Apples are the principal orchard crop.

ON the basis of information supplied by King, it is computed that the district has paid a rental of $12,835 for the debris basins from 1920 to 1937. If we exclude all other costs of the district such as the small annual maintenance and interest on the $30,000 of 30-year bonds issued to finance the improvements we find that the average rental cost for debris basins alone has been about 35 cents per acre per year for land protected. That this amount as an insurance against crop loss was fully justified can scarcely be doubted. According to King, it is anticipated that after the bonds have been paid off the annual drainage district special tax will not exceed $1 per acre. It appears from the facts at hand, without the benefits of an economic survey, that the drainage district has been a success with respect to costs versus benefits.

Looking at the other side of the picture, however, the total rental payments to date for the debris basins are equivalent to $12.70 per acre of watershed area. This compares with a cost of $8.51 per acre treated with soil conservation measures on the Muskogee, Okla., demonstration project, or an average cost of $6.09 per acre, for the gross acreage of the 37,000-acre watershed. It is higher than the total costs per acre on seven of the nine demonstration projects put on a maintenance basis at the end of the fiscal year 1937. Therefore, it appears that with the same or a smaller expenditure during the 17-year period for treating the Chase Creek watershed not only would the same protection have been afforded for the bottomlands but at least 415,000 tons of valuable soil (24.5 tons loss per acre per year) would still be in place instead of the debris basins. Soil conservation appears in this case as probably the most favorable alternative even if the debris basins had been constructed as insurance for the initial period of 2 or 3 years until proper land treatment was successfully concluded.

It is believed that two significant points are brought out by this study: (1) Treatment of a watershed of sloping upland solely to protect valley agricultural land to which it is tributary can often be justified from an economic standpoint. (2) Debris basins alone frequently offer a successful method of protecting valley agricultural lands, and adaptions of this practice may prove useful in operation work, under some circumstances, as a relatively cheap and expedient method of protecting bottomlands until soil-conservation treatment of tributary watersheds can be completed; or in very rare cases, use of debris basins may be the only or ultimately the cheapest method to employ.



Topographic map of debris basins, Doniphan County Drainage District, Doniphan County, Kans.

THE BERMUDA GRASS KING *by* Angus McDonald[1]

THEY will tell you in Fort Smith that Harry E. Kelly is the Bermuda Grass King of Arkansas. He is called the "Bermuda Grass King" because he has over 2,000 acres of Bermuda grass and because he has had it set all over Arkansas and the South and Southwest. His work with Bermuda grass has carried him to Australia and all over the United States.

The land south of Fort Smith is the poorest I ever saw. It is a mass of shale with a few inches of soil over it. In some places there is nothing but bare rocks. Some of the hilltops were once entirely bare—"bald knobs" they were called. It was a God-forsaken country; the soil was thin and washy and great gullies marred the hillsides. In 1887 Harry Kelly moved to the south of Fort Smith. Shortly after he became interested in Bermuda grass.

"I knew that a country could not be prosperous without good pastures," he told me. "When I came to this country in 1887 this field here had been farmed in cotton for 80 years. It was so run down that it wouldn't grow anything. The hillside was a maze of gullies, some of them as deep your head."

"Where are the gullies now?" I asked. I looked up the long slope that was covered with Bermuda grass from 6 to 8 inches high.

"Come on up to the top of the hill. I want to show you something," said Mr. Kelly.

I drove up the slope. When we got to the top I saw Bermuda grass growing on what was almost a solid mass of rocks. Some of the big, flat sand rocks were a yard across but they were nearly covered with the long Bermuda runners.

"Bermuda grass will grow where nothing else will," said Mr. Kelly. "It will stop erosion when nothing else will. There is more money in it than in corn and cotton and it builds up the land. Thirty years ago I carried a shoe box full of the roots to a farm I own in Ozark County, Missouri. From that shoe box I have set 300 acres. It will take this country. It will save the farmers in spite of themselves. It will choke out the cotton, overrun the fields. I had it set all along the roads and highways." He laughed uproariously. "It spread into the fields. It took the land. You see this 50 acre field? Twenty-five years ago it was a cotton field. But the Bermuda spread from the road. It took the field." Again he laughed, laughed so long and loud that I joined with him.

"These farmers' wives fuss at me. They are afraid their men will get the Bermuda grass fever. They don't like it because it spreads from the roads into their gardens and flowers."

"What about row crops? You've got to have row crops", I said. Mr. Kelly's jovial face changed. He scowled at me. "Row crops!" he shouted. "You don't need row crops with Bermuda. Row crops have caused this country to wash away.

"Other methods", snorted Mr. Kelly. "Yes, there are other methods, and compared to Bermuda none of them is worth a good cuss word. Bermuda is the only real soil saver."

"Have you tried other methods?" I asked.

"All I ever heard of—and quit them because Bermuda was better. You see that post there? I set that post 15 years ago 7 feet out of the ground. It is 3 feet high now. The sod has filled up 4 feet of soil. You see that ditch?" He pointed to a drain ditch alongside the road. "That ditch was over a horse's back 10 years ago. It was eating out into the road and into the field on the other side. I set it in Bermuda. Look at it now. Look at it now!" he said triumphantly.

I looked. The ditch was about 18 inches deep. Its walls and banks were matted with Bermuda and long fingers of grass were reaching toward each other from either side in its bottom.

"We have to plow that ditch every year or two to keep it from clogging up. And you talk to me about other methods!"

We drove by pasture after pasture of Bermuda grass where fat cattle grazed. We drove over hill and dale, over rocky land, thin land, good land, bad land, and the Bermuda was thriving everywhere.

"I have lots of trouble getting these farmers to take care of the pastures. You see this farm here?" said Mr. Kelly. "Fifteen years ago I had it rented. It had been set in Bermuda grass in 1904 and needed plowing badly. But the fellow wouldn't plow it. 'No', he said, 'I'm not going to ruin that Bermuda by plowing it up.' Well, he owed me $4,000 and I had renewed the note twice, and I said, 'Well, if you don't plow that pasture up I won't renew your note.' The fellow went around to the other banks and tried to get some money, but failed, and so he came back and said, 'All right, you win.' He plowed up the Bermuda and it helped it a lot, but it needs plowing again."

[1] Formerly Assistant Soil Conservationist (Erosion History), Section of Climatic and Physiographic Research, Soil Conservation Service, Washington, D. C.

"Have you developed any superior varieties of Bermuda?" I asked.

"Well, I've experimented a great deal. I've tried a great many varieties, but the kind that has been growing here the longest is the best and hardiest. It has become acclimated. There is a plat of Bermuda near the old fort that is 104 years old. I talked to an old soldier in the early days who saw it set out in 1833. It is still doing fine. I have brought many other varieties here from many parts of the world. I've got varieties from Arizona and Australia, but it froze out. Bermuda's worst enemies are cold and shade. It will grow in rather open timber, though. Look at that." I stopped the car. Not far off there was a good stand of Bermuda growing among some red oak trees.

"Well, I should say there's another enemy and that is dog fennel. These farmers won't pasture their Bermuda enough and the dog fennel comes. To do well Bermuda ought to be pastured a good deal. There's not enough cattle in this country. Bermuda will support from three to five head of cattle to the acre. Show me another grass that will do that. Yet some of these farmers are afraid of it.

"But let me tell you about the time I went to Australia. Did you know that New Zealand was one of the richest countries in the world? Did you know that New Zealand exported more butter than any country in the world and that it is all on account of Bermuda? I was going over on the boat in 1904 to Australia and I got to talking with an Englishman who said he had a little ranch of 7,000 acres he had just sold for $200 an acre. He said they raised Cooch grass on it for pasture. Said it was the finest grass in the world. When we got across he took me out and showed me some of this Cooch grass. What do you think it was? As fine Bermuda as ever you saw! But that Australian Bermuda isn't as good for this country as what grows here.

"Bermuda Grass Mitchell has developed some fine varieties. But none of them is any better than this grass around Fort Smith. Mitchell has done a lot, though. He got the Bermuda grass fever along with me and John Fields in the early days. We made speeches all over this country. And every time we wrote an article we harped on Bermuda. John Fields and I made a Bermuda compact in 1902. He was editor of the Oklahoma Farm Journal. He agreed never to publish an issue of the paper without an article on Bermuda. And he carried out the agreement as long as he was editor. But we lost him," Mr. Kelly said, sadly, "He went in with the farm-loan people. That was a good many years before he died."

"I guess you have sold a lot of the Bermuda roots", I said.

"Sell it! I should say not. I've never sold a single sprig. But I've given it away. I've given away thousands and thousands of sacks of the sod. They come here and dig it up free of charge.

"One of the chief obstacles to spreading the Bermuda grass light", went on Mr. Kelly, "has been prejudice. The foremost farmer in this country today has been saved by Bermuda grass almost against his will. That's Claude Hampton. Claude Hampton worked for me for 9 years and I never could convert him to the Bermuda grass doctrine. Annie, his wife, said his mother hated the grass and I reckon Claude had a prenatal antipathy to it. Annie said if you showed Claude a sprig of Bermuda he would spit at it like a kitten does at a dog. Claude had a fine bottom farm, over 200 acres, and he wouldn't allow Bermuda on it. Well, in 1927 the great flood came and covered all his land with a layer of white sand from 6 inches to a foot deep.

"Claude came to me and said, 'Well, Mr. Kelly, I'm ruined. The water has ruined my land.'

"I said, 'Claude, why don't you set it in Bermuda?' But Claude just laughed. He had heard me harp on Bermuda so much.

"Well, the next thing I knew Claude had got some Bermuda seed from Arizona. You ever been in Yuma, Arizona? Did you know there was a seed mill there that has developed machinery that will separate alfalfa seed from Bermuda seed? Well, anyway, Claude sowed his land in Bermuda in May and got a fine stand.

"The best way to start Bermuda though is from the roots. I use a manure spreader to scatter it and then turn it under with a turning plow."

While Mr. Kelly was talking we had been approaching the edge of the Arkansas River bottom. In front of us was a comfortable-looking farm house surrounded by a Bermuda grass lawn. The house was situated on a rise just above the bottom.

"Look at that Bermuda grass pavement," said Mr. Kelly. The Bermuda grass had almost covered the road in front of the house. "This is where Claude Hampton lives."

We got out and I met Hampton and he drove us down into the bottom. Before us stretched 200 acres of the finest Bermuda grass I ever saw. Most of it stood 12 inches high.

"How long will Bermuda live under water?" I asked Mr. Kelly.

"Well, I don't know. Never have known water to stand on it over 4 or 5 months. It always came out."

"In this pasture is about 100 acres," said Mr. Hampton. "I've got 125 head of cattle on the grass. You can see they haven't eaten a tenth of it, and they are fat as butter."

We stopped near a grove of trees where a bunch of cattle were shading. They were as fat cattle as ever I saw.

"I don't feed 'em a thing the year around. They live on Bermuda through the winter," said Mr. Hampton.

"Did I tell you about the time I converted the packing house people to Bermuda?" asked Mr. Kelly. "Well, the packing house man traveled around the country looking for a place to locate. I had been talking pasture and cattle to him but he said this wouldn't make a cattle country. 'Your grass ideas are all right', he said, 'but it would take too long.' 'Now you look here', I said, 'I want to show you something.' I took him down to this bottom about 9 o'clock one morning and it was 10 o'clock before he was ready to leave. He was converted all right, and that's how Fort Smith happened to get the packing house."

"I guess they might call you one of Mr. Kelly's disciples," I said to Mr. Hampton.

"I guess they might", said Mr. Hampton. "Mr. Kelly kept telling me to quit work. I just sit in the shade and watch the cattle get fat."

The second bottom near Hampton's house was set in Bermuda too—but part of it had grown up in weeds.

"Claude, how about plowing this up?" said Mr. Kelly. "It would help the Bermuda."

"Well, you know you told me to quit work and I'm trying to follow your advice," said Claude.

Driving back to the house Mr. Kelly said, "I have spent 50 years carrying the Bermuda gospel. When I was a young man I decided to devote my life to Bermuda. And I have. Or most of it. I am 76 now."

Sambucus canadensis, the common elder.

A Border for the Woods

By William R. Van Dersal [1]

IF plantings are to conserve soil on the poorest, steepest land, some provision must be made to ensure health and vigor to trees as they grow older. This involves precautions about woodland edges. Edging the woods with a border of shrubs is one way to give protection.

Anyone who has seen virgin timber after a portion of the tract has been logged-off knows what damage wind can do to trees.[2] A shrub border protects the woodland from drying winds by forcing them up and over the trees, thus preventing the air currents from sweeping through the woodland to blow away litter, dry the humus layer, and prevent satisfactory reproduction. Planting a proper shrub border is tantamount, in a sense, to streamlining a tree plantation. In the Plains area, successful establishment of tree windbreaks depends upon low-growing, protective plantings on both sides.[3] [4] [5] Examination of undisturbed natural woodlands always shows a bushy border—as any picnicker who has ever tried to get into the woods from the road can attest.

Shrub borders also cause better development of the edge trees, inasmuch as the crowding of shrubs against the trees results in natural pruning. Trees at the edge of a plantation always develop sturdy limbs on the outer side, and these make poor timber. But when tall shrubs shade the trees, only slender limbs develop—and these are later lost.

A PROPERLY planned shrub border attracts to the woodland various species of birds. It is well known that woodlands without diversification, especially if composed of one species, harbor a relatively small feathered population.[6] It is also painfully evident at times that insect damage and insect-borne disease becomes a serious matter in many woodlands. European foresters have attempted to attract insect-

[1] Biologist, Section of Wildlife Management, Soil Conservation Service, Washington, D. C.

[2] Troup, R. S. 1928. Silvicultural Systems, 199 pp., illus. Oxford. See particularly pp. 8, 68, 93.

[3] Olson, D. S., and Stoeckeler, J. H., 1935. Possibilities of Shelterbelt Planting in the Plains Region. Sec. 4—The Proposed Tree Plantations—Their Establishment and Management, pp. 15–27.

[4] George, E. J., 1936. Growth and Survival of Deciduous Trees in Shelterbelt Experiments at Mandan, N. Dak., 1915–34. U. S. Dept. Agr. Tech. Bull. 496, 48 pp., illus., p. 43.

[5] Sholz, H. F., 1935. Causes of Decadence in the Old Groves of North Dakota, U. S. Dept. Agr. Circ. 344, 37 pp., illus. (See p. 32.)

[6] Forbush, E. H., 1908. Useful Birds and Their Protection. 437 pp., illus., Mass. State Bd. Agric., Mass. See especially pp. 90–110.

A natural border of shrubs on the edge of a woodland in Vermont.

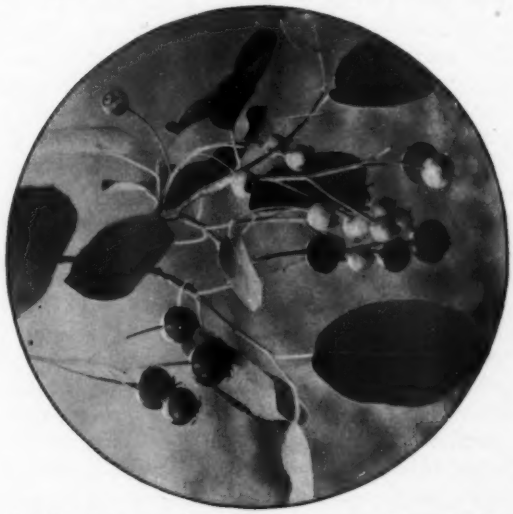
Mulberries are widely known for their attractiveness to birds. They grow well on woodland edges.

eating birds into nondiversified woodlands by placing birdhouses in their plantings. Shrub borders, however, coupled with uneven-aged stands and occasional openings, are more effective in holding large numbers of birds near woodland areas. The fruiting shrubs, it may be added, provide food for fur bearers, many of which include a considerable percentage of insects in their diets.

Plants valuable for borders fall into four classes: Small trees, tall shrubs, low shrubs, and vines.

The small trees of value in such plantings include juniper, flowering dogwood, osage orange, hawthorn, persimmon, mulberry, mountain ash, wild black cherry, pin cherry, boxelder, and hophornbeam. All these have value for birds. Incidentally, junipers and hawthorns are never planted together because the cedar-apple rust depends upon these two, among others, for its development.

THE tall shrubs that may be planted outside the small trees include viburnums, sassafras, wild plums, shrubby oaks, sumacs, service-berries, hazelnut, honeysuckle, elderberry, prickly ash, shrubby dog-



Amelanchier canadensis, *serviceberry. These fruits, ordinarily produced in the open but less commonly inside the woodland, are of importance in many bird diets. This and other serviceberries readily find a place in border planting.*

woods, hollies, shrubby hackberries, and crabapples. In the West, manzanitas (*Arctostaphylos* spp.) and ceanothus may be used in addition. Russian olive, caragana, and lilac are shrubs of considerable importance in windbreak planting, although the latter two furnish little food for wildlife. Species that appeal particularly to birds should be—and are—selected.

The low shrubs planted outside the tall ones may include wild blackberries, callicarpa, snowberries, coralberry, dwarf papaws, chokeberries, wild roses, and even low-growing wild cherries, all of which produce food sought by birds.

Cornus paniculata, *one of the shrub dogwoods useful in woodland borders and of value to wildlife.*

Vines are advantageous along woodland edges. It makes little difference how vines clamber over the border plants. In fact, the more luxuriantly they develop, the better protection the border offers to the trees inside. Vines planted inside the woodland may often be serious competitors of trees. When old vines are already present they can profitably be left to supply wildlife food, but in new plantings vines ought to be planted in the edges. Grapes of all kinds are acceptable to scores of birds as well as man himself. Virginia creeper, smilax, bittersweet, and other climbers may be expected to encourage bird life as well as to consolidate the border.

The practice of woodland border planting fosters two land uses—the production of wood products and the production of wildlife. Here, certainly, multiple land use and erosion control is achieved by a method that combines several practices into a harmonious whole.

Viburnum dentatum, *one of the viburnums adaptable to border planting and valuable for wildlife.*

Wild grapes figure prominently in scores of bird diets. They can be used to make the woodland-protecting border more dense.

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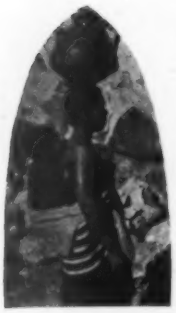
FOREST DESTRUCTION AND SOIL EROSION IN MADAGASCAR

By Charles F. Swingle [1]



Because of an old legend, Madagascar has been referred to as "The Land of the Man-Eating Tree." Due to the ruthless way in which the natives have destroyed their once magnificent forest, however, the appellation might well be "The Land of the Tree- Hating Man." As in most countries, the development of agriculture in Madagascar has necessitated some clearing of forests. One can understand, even if not condone, the careless disregard of the native, living in the midst of vast forested areas, for a few trees. With a limitless reserve of wood at hand, why take thought of the future in clearing for the all-important rice culture?

THROUGHOUT the centuries, as the forests disappeared gradually and were replaced by highly inflammable grasses, the burning of vast areas by hand-set fires became common practice. At the present time the only limit to the fire is the lack of anything to burn. And, strangest of all, with the almost complete destruction of the forest and the consequent dependence upon a timber supply at considerable distance, there appears to be no change as regards the Malagasy's odium for trees.

The Rain-Forest

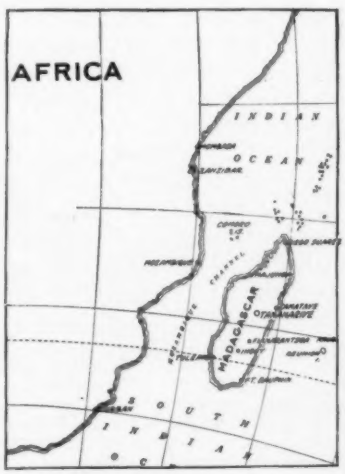
Originally, almost the entire area of France's "Great African Island" was covered by a dense forest. Today almost nothing remains of it except a strip of mountainous rain-forest 50 miles wide lying along the east coast, bordering the Indian Ocean. Here, even though there has been considerable exploitation of valuable tropical timbers, soil erosion is negligible, for with the almost continuous rain-fall, when the cover is removed it quickly replaces itself.

Central Plateau Conditions

On the other hand, the broad central plateau, some 200 miles wide and extending almost the entire thousand-mile length of the island, is characterized by more of a continental climate, with definite seasons of rainfall and comparative drought. In this region, holding the greater part of Madagascar's 4 million inhabitants, rice culture is of paramount importance, with everything else secondary. Where original forest remains it is cleared by burning, with the natives giving no concern to the spread of fire beyond the confines of the planned rice field. Then, after but 1 or 2 years of high yields, the field is abandoned and the process repeated as long as any forested land remains. Unlike the condition on the east coast, however, because of the well-defined dry season and the soil characteristics the abandoned area does not come back to forest but yields instead only a scanty covering of inflammable grasses. Thus the hand of man combines with the burning tropical sun in transforming what was previously a fertile forest soil into a sterile, erosive, red, brick-like laterite. Hence another designation commonly given to Madagascar, "The Island of Red Rivers."

Region of Climatic Seasons

The western third of Madagascar, again extending almost its entire length, presents no sharp line of demarcation from the central region. The central high plateau slopes gradually toward the Mozambique Channel. The seasonal difference in climate becomes much more accentuated. Notwithstanding an annual rainfall of some 60 inches, the yearly cycle is so sharply divided between a wet and a dry season that the vegetation goes through much the same stages as in a more temperate country, with the leaves of many of the plants falling at the start of the dry season.



[1] Horticulturist, Section of Conservation Nurseries, Soil Conservation Service, Washington, D. C.

Formerly most of Madagascar was forested.

In traveling through the region of the west during the dry season, I have counted as many as seven distinct fires on the horizon at one time—probably each set by human hand. Here again the principal reason for fires is to make way for the rice field. In the west, however, rice culture gives way to livestock raising and doubtlessly many of the fires are set, as in our own country, with the mistaken idea that the best way to get a new grass cover is to burn off the old.

The continued burning reaches ever farther into the remaining stands of the original forest, so that these are limited more and more to rock-protected areas inaccessible to the fire. Once the fire reaches one of these forest remnants, it is gone forever. In neither the central nor the western part of Madagascar is the forest ever able to overcome the insurmountable obstacles of high temperatures, tropical insolation, heavy downpours alternating with long periods of drought, and a lateritic subsoil.

A very few species of trees, however, are able to make a feeble stand against the constantly recurring grass fires. As a result, these, along with a small number of grass species, make up the entire plant cover, meagerly replacing one of the richest floras of the world with an open savanna.

Rice-field terracing seems to reach its highest development in Madagascar.

The forest gives way to the rice "tavy."

The final stage of destruction on the plateaus is represented by a sparsely-grassed plain, with usually only two or three species of trees and with regularly spaced termite nests visible as far as the eye can see—certainly a desolate substitute for the magnificent forest which once occupied this land.

Erosion Follows Fires

Under such conditions the slopes are subject to devastating erosion, and the streams are choked with the soil carried down from above. And as an inevitable consequence, the characteristic picture of the country becomes the native with a jug, carrying water, and all too frequently from great distances.

The extreme southwest of Madagascar represents a continuation of the western part of the island in that it also has well-defined seasons. But here the rainy season is so short and uncertain as to actual rainfall, and the dry season so long and pronounced, that grass is able to make but little growth. Hence, because of its lack as the fire-propagating medium, the flora of the southwest is essentially the same today as it has been for centuries, and erosion is negligible, one of the few exceptions being the locally important but very limited sand dune erosion taking place along the shore of the Mozambique Channel at the mouth of the Linta River.

Devastation Nearing Completion

Looking at Madagascar as a whole, if we except the relatively small areas of the southwest where erosion is largely absent because of the lack of fire-propagating grasses, and of the east coast where it is too wet at all times for fire, we see that the magnificent tropical forest of the earth's fifth largest island has just about disappeared, due chiefly to hand-set fires. Many valuable species of plants are gone completely, and with the forest have gone the unique animals. And, as pointed out by the French observers, the disappearance of the forest accentuates the dryness of the air and soil, rapidly culminating in the washing away of all soil down to the rock.

Thus, rapidly are disappearing the natural riches of one of the most fertile areas of the world.

POST-WAR AGRICULTURE AND SOIL EROSION IN CZECHOSLOVAKIA

By Guy R. Stewart[1]

THE Republic of Czechoslovakia is made up of five districts which were largely in Austria-Hungary prior to the World War, with a small portion which was taken from German Silesia. The western portion of the republic consisting of Bohemia, Moravia, and Silesia, in most places ranges from hilly to mountainous with some broad and fairly fertile valleys. Prior to the war these districts produced a surplus of rye and barley for export. Slovakia, lying farther south, forms a part of the great Hungarian plain and is composed chiefly of excellent agricultural land which normally produces a surplus of wheat. Farther to the east, Ruthenia lies in the foothills of the Carpathians and, although it has a relatively limited production of grain, there has always been a considerable return from livestock and forest products. In the western portion of the Republic there are approximately 5,200,000 people who make their living from manufacturing and general industry while only 3,400,000 are engaged in agriculture. The soils of this part of the country are not sufficiently rich nor is the climate uniformly

Gully treatment in the Rakovník area (middle Bohemia).

[1] Assistant to the Chief, Division of Research, Soil Conservation Service, Washington, D. C.

favorable for successful farming. Slovakia, on the other hand, ordinarily produces a surplus of foodstuffs. The Republic, as a whole, is usually classed as being largely self-supporting.

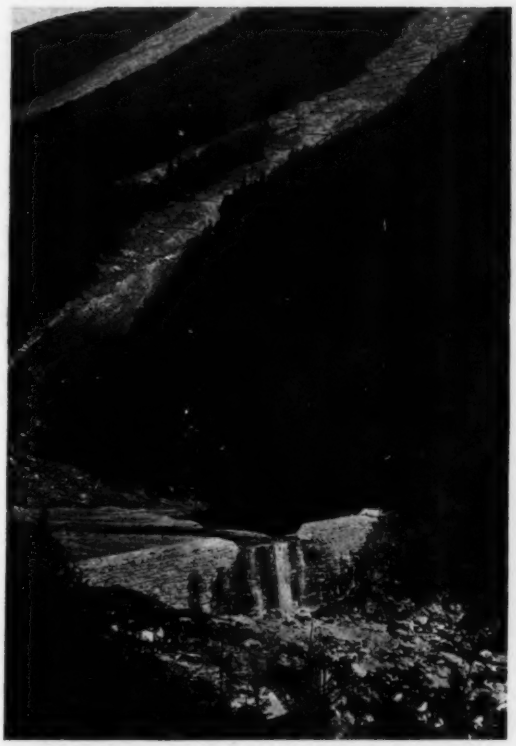
Land Reform

Following the World War there was an expropriation of the larger holdings of agricultural land similar to that of Rumania. Out of a total of approximately 35,000,000 acres consisting of tillable land, pastures, and forest, about 9,500,000 acres were expropriated for sale to peasant operators. With this change in landownership there is some tendency for a decrease in the acreage sown to wheat which is more than made up for by a gain in the area planted to legumes, vegetables, and forage plants. There likewise is an increase in the land devoted to pastures and meadows.

Strip Land Erosion

Certain striking erosion conditions in Rakovnik, Bohemia, and in the basin of the Borsavy River in the Carpathians are described by Valek.[2] In these areas the soils are composed of rather deep sedimentary deposits containing an appreciable amount of gravel. Erosion in both areas appears to have been caused by the cultivation of unduly steep cropland having a gradient of 10° to 40°, as well as by overgrazing on upland pastures. As a result, there has been excessive run-off following rainfall and much debris and gravel has been washed down into the lower valleys. In places, gullies have developed so rapidly that the smaller stream channels into which they feed are practically swamped with mud.

On the grassland, the condition appears to have been intensified by a loss of pasture fertility owing to long continued grazing without proper fertilization. These conditions have been treated by retirement of the steepest slopes to woodland and by regulated grazing in the upland pastures. It is now proposed to treat watersheds such as these in a more comprehensive fashion and Valek [3] has published a plan for systematic improvement of the watershed basins of the Kychova and the Zdechovka Rivers. Figures on precipitation and stream flow have been gathered for the period, 1928–34, and it is planned that this work be extended into the future with a concerted attempt to relate the run-off to the land-use practices.



Condition and treatment of gullies in Hučivé Děsné area (northern Moravia).

[2] Valek, Zd. Manuscript communication—Report on Soil Erosion in Czechoslovakia.

[3] Valek, Zd. Recherches et Resultats De L'Etude De L'Influence De La Vegetation Sur Le Debit Des Eaux De Precipitation Dans Les Bassins Des Torrents De La Kychova Et De La Zdechovka Pour Les Annees 1928 a 1934. Recuil De Travaux Des Instituts Des Recherches Agronomiques De La Republique Tchecoslovaque. Svazek 144. Vol.

Contour Furrows Constructed Without Loss of Sod

By Merle W. Bloom [1]

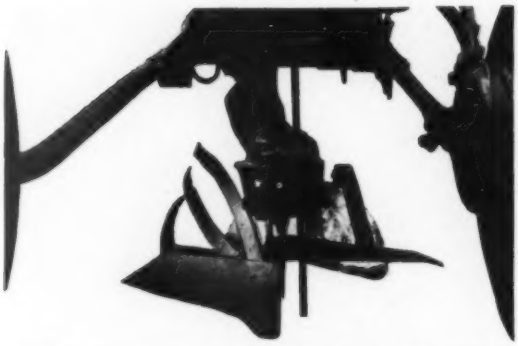
View of furrows and ridges plowed by the contour-furrowing machine on a pasture in northeastern Iowa, three months prior to date of photograph.

AN implement that will build furrows and ridges without destroying the sod has long been needed for the establishment of contour furrows on pasture slopes. Such a special contour-furrowing plow which does not turn the sod, has been developed in Iowa.

The original plow was designed and constructed in cooperation with E. V. Collins, research professor in agricultural engineering at Iowa State College, on the Soil Conservation Service demonstration area at Marion, Iowa. The plow has been used successfully on the project area at Marion and in the camp areas at Eldora, Maquoketa, and McGregor, Iowa.

This machine was built from a standard 18-inch single-bottom plow. The moldboard was replaced by three spring-steel sod lifters which are attached so that they will not turn the sod over but will hold it at a

[1] Assistant agricultural engineer, Soil Conservation Service, Indian Creek watershed, Marion, Iowa.



Front view of contour-furrowing machine showing plowshare with three sod-lifters at left and sod-cutter blade with two sod-lifters at right, and soil-moving scraper-blade in background.

60° angle. An 18-inch sod-cutter knife was mounted on the left and 4 inches higher than the regular share edge. To the rear of this knife is welded two spring-steel sod lifters which raise the left-hand or uphill strip of sod.

A SCRAPER removes the underlying soil to a depth of 4 inches and pushes it under the right-hand strip. As the sod is allowed to drop in place, the downhill strip is held up by the soil that has been placed under it to form a ridge, and the uphill strip settles down where the soil has been removed to become the bottom of the furrow.

The ridge is held approximately 6 inches above the normal level, while the furrow sod settles to 3 inches below. Thus, an effective ridge is produced to extend 9 inches above the furrow bottom. Heavy concrete rollers behind the plow press the sod firmly in place thus securing good contact between the sod and the soil underneath. The roller also smoothes out the ridge and leaves it at a uniform height.

THE cost of constructing the original contour furrowing plow, including all materials and labor totaled $181.23, the approximate price of a two-bottom tractor plow.

It is estimated that contour furrows can be plowed on about 10 acres of pasture a day with this machine. Labor requirements consist of two men to survey for the furrows and a tractor operator to handle both the tractor and the plow. The contour-furrowing machine can be operated from the tractor as with any standard tractor plow. The power requirement varies for the Carrington, Tama, and Clinton soils of eastern Iowa, from a 2-plow tractor for the lighter soils to a 20-drawbar horsepower track-type tractor for the soils with more compact subsoil layers.

HERETOFORE the terracing equipment and turning plows used in building terraces and furrows on pasture destroyed from 5 to 20 percent of the sod cover. In contrast, the new contour-furrowing plow establishes uniform furrows without any loss of sod. This maintenance of the original sod does away with the necessity of reseeding and provides a protected furrow to hold the rainfall, resulting in increased savings of soil and moisture and subsequent increased pasture returns.

Work has been done on slopes ranging from 2 to 18 percent. Furrows are spaced from 10 to 20 feet apart, the spacing being designed in such a manner that the furrows will retain a total rainfall of 1½ or 2 inches regardless of infiltration. It is recommended that furrowing with this plow be done, in areas where climatic conditions are similar to eastern Iowa, between September 15 and June 1. During this period, there is more likely to be sufficient moisture in the topsoil to permit proper construction of the ridge and to assure continued growth of the loosened sod.

The furrows made by the machine have not been in use long enough to determine entirely their effectiveness. On one pasture furrowed by this plow, however, it was observed that there was no run-off following 4 inches of rainfall in less than an hour, a rain of about 25-year frequency. Furrows without loss of sod, resulting in sodded water furrows and sodded ridges, constitute a distinct advantage, and this plow should become an important item in soil and moisture conservation on pasture land.

Back view of furrowing machine, showing sod in place after ridge is built and packed by concrete rollers.

A second machine has been constructed, consisting entirely of plow parts in stock production. The standard plow bottom used on the original machine is replaced by a 16-inch right-hand sod bottom, and a 16-inch left-hand sod bottom is used in place of the sod cutter and sod lifter. A 10-inch right-hand turning plow bottom is substituted for the original scraper.

Erosion usually must be controlled before soil fertility can be increased.

Grass is an inexpensive, effective weapon that nearly all farmers can use to check soil and moisture losses.

OPPORTUNITIES FOR THE CONTOUR BALK METHOD

By B. H. Hendrickson [1]

THE contour balk method is as yet practiced to only a very limited extent in the Southeastern States. It has evolved gradually as a method by which winter annual legumes successfully maturing seed may be permitted to self-seed the fields year after year, certain summer row crops being grown in wide rows between the ripening legume balks. Winter legumes used in Georgia have been mainly crimson clover, southern spotted-leaf bur clover, hairy and Augusta vetch. Summer crops have been principally corn with cowpeas, soybeans, or velvet beans, and some cotton.

In land preparation for summer crops in wide rows, the general practice has been partially to break the winter legume land by contour turn-plowing outward in single rounds, or "bedding out", leaving unbroken winter legume balks about a foot wide between the plowed strips. Corn is generally planted, 5 to 6 feet apart, in the waterfurrow rows so formed.

In the balks the winter legume seeds ripen in May to early June, the corn being cultivated as usual. At the last corn cultivation, the balks between each pair of corn rows are broken out. This operation scatters the winter legume seeds for a volunteer stand in the fall. Cowpeas may then be interplanted, between corn rows.

A large Georgia farm has used this method continuously for about 15 years, principally in connection with corn and companion summer legumes, on Cecil sandy loam. Now the topsoil is dark-colored and productive, since the organic matter and nitrogen needs have been amply supplied by repeated legume cover cropping and green manuring. The winter cover crops used have been mainly crimson clover mixed with Italian rye grass, both of which have volunteered dependably in the balk plan on this farm. Good contour culture is practiced. In fact, the farmer has plowed out his terraces, claiming they were no longer needed. Crop yields are improving, with less fertilizer used than formerly.

There is little question as to the efficacy of the method in reducing erosion losses to low figures, and improving the soils rapidly. The features include protective winter cropland coverage plus the use of narrow buffer-type temporary contoured resistant strips at very close spacings. The protective effects of the residue materials, good contour culture and summer row crops during the late summer and early fall periods serve to complete the annual cycle of soil protection and soil improvement. Considerable reduction of run-off is probably obtained.

This simple plan of cropland management has many points to commend it. The trouble with it lies, however, in the fact that the average farmer has difficulty in making it work.

The reasons, mainly soils-agronomic in nature, lead back to the well known truism that poor eroded lands produce poor crops. Good farms tend to succeed with winter legumes and a variety of other crops during good and poor seasons; poor eroded farms generally succeed only with drought-resistant poor-land crops and then only in favorable seasons.

Unfortunately, the croplands most in need of the contoured balk method seem unable to use it. Such farms generally depend on cotton, and for this crop it is necessary, for satisfactory yields under boll-weevil conditions, to provide clean, well-prepared seedbeds for rapid early growth. Any practice which interferes with cottonfield land preparation, hinders good germination, or delays growth of cotton, is likely to be discarded as impractical, particularly on small hill farms which are moderately to seriously eroded.

On the other hand, there is little doubt that the contour balk method will work on better croplands on dairy farms, livestock farms, or well equipped farms in general upon which considerable acreage is devoted to production of feedstuffs. Improved winter legumes which grow well and produce seed that does not volunteer until the advent of cool weather are badly needed. If an early maturing type of winter clover can be found which upon ripening will not appreciably compete for soil moisture with seedling cotton growing in nearby rows, then in all probability cotton can enter the contour balk picture. When that time comes, we shall have the makings of a soil conservation method for croplands of far reaching significance.

At the present time many farmers in Georgia are using a variation of the method in a cotton and corn 2-year rotation. Contour balks of winter legumes remain in corn to self-seed for the following winter's stand, the stand being plowed under early the following spring in preparation for cotton.

[1] Superintendent, Southern Piedmont Experiment Station, Soil Conservation Service, Athens, Ga.

THE "SPREAD ROW" SYSTEM FOR LAYING OFF ROWS

By B. L. Taylor [1]

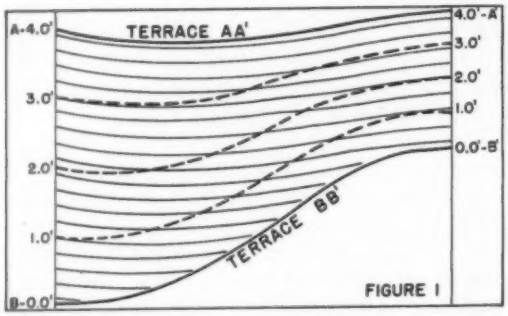


FIGURE 1

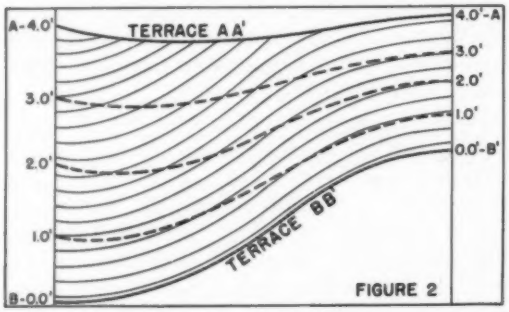


FIGURE 2

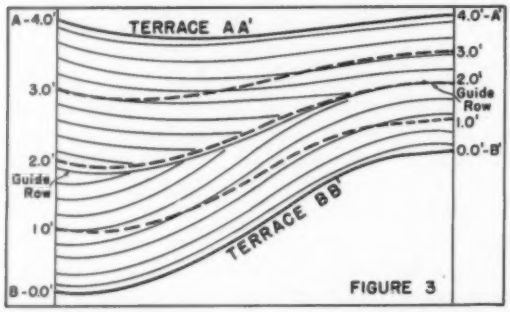


FIGURE 3

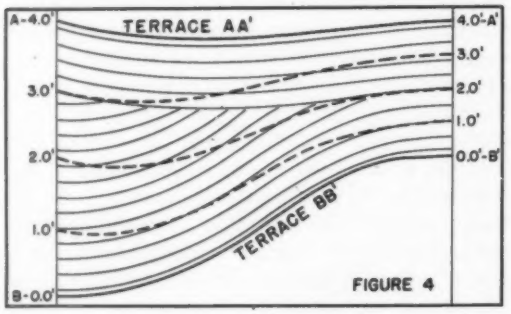


FIGURE 4

AFTER a farmer's fields have been properly terraced, the question he asks most frequently is, "How should I lay out my rows?" The "spread row" system, presented in the following discussion, was worked out in the effort to find a definite answer to that question.

The system is not offered as a final solution to the problem. It is presented rather as a suggested method which may serve as a basis for further discussion and, in the meantime, one which will provide the farmer with a workable plan. Such a system should be flexible, in order that rows can easily be changed when excessive grade or bagging occurs.

One or more places will usually be found in the water furrow of most rows, where a stump, a short high place or other obstruction will prevent flow to the outlet. Or, a break in a row will permit the water to flow from the water furrow to a lower level instead of going to the outlet, as was intended. For these reasons, it is assumed that a row should not be expected to control all of its own water.

The surplus water not able to reach the outlet by flowing along the furrow between the rows, should run at low velocity over the tops of the lower rows on the flatter slopes (between the terraces). These flatter slopes usually will have more topsoil as well as more vegetative cover, thereby being more resistant to erosion than the steeper, more eroded slopes.

Under the spread-row system it is assumed that rows should be on the contour, or should have as little fall as practicable. Ends of point rows should point to the first long row above. Seldom should it be found desirable to lay off point rows in such a manner that one end will be in the terrace channel. The longer point rows of each set should be run parallel to the adjacent long row below.

Guide rows should be laid off with the same grade as adjacent terraces. One guide row at half the terrace interval should divide the area between two terraces into two areas that are approximately equal. Two guide rows should divide the area between two terraces into three areas that are of approximately equal area, etc.

For illustration, consider a segment between two terraces where at one end the slope is such that there

[1] Engineer, Soil Conservation Service, Meridian, Miss.

is a space 18 rows wide; at the other end of the segment the slope is twice as great, but the space is 9 rows wide. Also assume a difference in elevation of the terraces of 4 feet. Then (using the recommended practice of having the crest of the terrace as a "middle"), should the rows be laid off with the terrace above the result would be a system as shown in figure 1.

In figure 1, as well as subsequent figures, the numbers at each end of the segment refer to the probable elevation of different points at the ends of the segment between terraces. The dashed lines are contour lines indicating the probable elevations of different points within the segment.

The vertical interval (difference in elevation) between the points A and B is 4 feet. The vertical interval between A′ and B′ is also 4 feet, but the horizontal interval is considerably less than the horizontal distance between A and B, as can readily be seen in the figure.

Now the vertical interval *per row* at the space A B can be obtained by dividing the total vertical interval, which is 4 feet, by the total number of rows, which is 18 at the space A B. This division of 18 into 4 gives the vertical interval per row at the space A B as 0.22 foot.

Also, the vertical interval per row at the space A′ B′ is obtained by dividing the total vertical interval, or difference in elevation between A′ and B′ which is 4 feet, by the number of rows, which at the space A′ B′ is only 9. Dividing 9 into 4 gives the vertical interval per row at the space A′ B′ as 0.44 foot. Then, at row no. 9, for instance, the elevation at the A B space would be 2.0 feet above terrace B B′, giving a fall in row no. 9 from A B space to A′ B′ space of 2.0 feet. Carrying this discussion one step further, and assuming that the terraces have a fall of 0.1 foot per hundred feet from A′ and B′ toward A and B, respectively, and the distance approximately 200 feet, row 9 would have a fall of 1.8 feet, in the opposite direction from the way the water flows in the terrace channel. Also, should the terraces have 0.1 foot fall per humdred feet from A and B to A′ and B′, respectively, row 9 will have a fall of 2.2 feet, in the 200 feet, but in the same direction as the grade of the row.

Note how rows deviate from contour (dashed) lines in the figure.

Using the same illustration, but laying out the rows parallel to the lower terrace, a system as shown in figure 2 will result.

This system has approximately the same disadvantages as the other, except that silt is not deposited in the terrace channel, as where the rows are laid off as illustrated in figure 1. Also, there will be the disad-

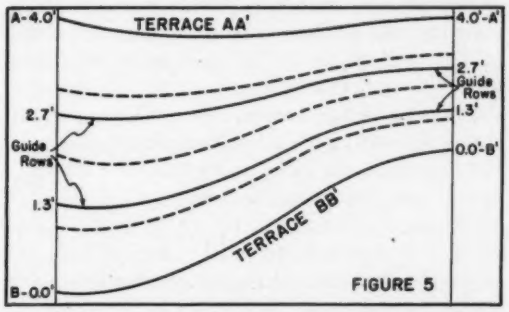


FIGURE 5

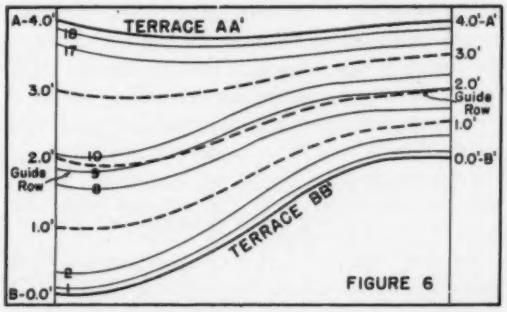


FIGURE 6

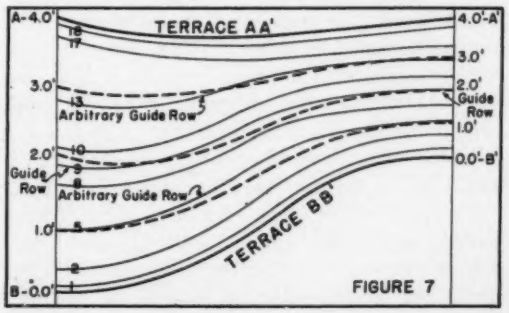


FIGURE 7

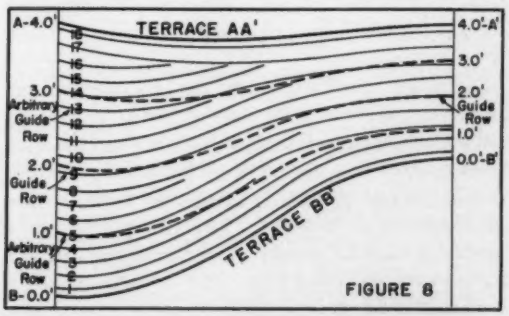


FIGURE 8

vantage that, should the terraces run either way, the surplus water will concentrate on the space A B.

Now, using the same illustration, suppose that a guide row be laid off on the 2-foot elevation between the terraces and the rows be laid off as before. Thus, using both the systems, and running the rows parallel to the upper terrace on the upper part, and parallel to the lower terrace in the lower part, a system as shown in figure 3 will result. By dividing the terrace area as shown in figure 3 into two parts by the guide row, conditions are twice as good as those shown in figure 1 and figure 2, with less deviation from the contour lines.

Figure 4 illustrates the usual system of laying off rows now employed by farmers in the Southeast when no guide row is used.

This system is laid out by laying off the long rows parallel to the upper terrace until half way down to the terrace below in the most narrow place (as A′ B′ space), then laying off the rows parallel to the lower terrace, including both the long and short rows, with the short rows pointing into the long row above. In the absence of the guide row or rows, this is perhaps the best system yet used. One or more guide rows would improve this system considerably.

Referring to figure 5, it is obvious that whichever way the rows are laid off, the results should be at least three times as good as the system illustrated in figure 1 and figure 2, as well as an improvement on the system illustrated in figure 3. This brings the discussion to the point where it would be well to consider the practicability of spreading out the point rows throughout the terrace interval.

By the term, "spreading out the point rows" is meant having the long rows interspersed with point rows, preferably, in two's. An odd number of point rows is undesirable, because in cultivating with one-row cultivators, or one furrow to the row with any plow, the operator must go back to the end of a row to start another row. However, the space on the last part may demand an uneven number of point rows.

Determine from looking over the area between terraces the number of guide rows required. If the area between the terraces is fairly smooth, of about the same slope and not very wide, one guide row may be used. Should the area be rough, or more than twice as wide on the flatter slope as at the most narrow place, two guide rows should be used. Three guide rows may be advantageously used on the more difficult areas. As the procedure is the same for laying out rows according to the spread row system for two or more guide rows as for one, one guide row will be used in the illustration of the practical system of laying out rows on the contour.

Lay off a guide row at the 2-foot elevation, or midway between the terraces. Then lay off two rows below the crest of the terrace above with the top row a half space below the crest of the terrace. Also, lay off two rows above the crest of the lower terrace with the first row a half space above the crest. Now, lay off the guide row with one row on each side, giving the guide row the same grade as would be given if it were run as a terrace. Up to this point, seven rows have been laid off with the system partially completed as shown in figure 6.

Note in figure 6 that the rows 2, 8, 10, and 17 are less accurate than 1, 9, and 18, but will be accurate enough for practical purposes. Also, the rows 1, 2, 17, and 18 will be on part of the terrace and not subject to better treatment.

Now two wide spaces are left. By arbitrarily "splitting each area open" with a furrow, four open spaces of smaller size are left, giving a figure as shown in figure 7.

The so-called "arbitrary" guide rows can be put in by any experienced plow man with fair accuracy and will approximate the accuracy of a guide row.

Figure 8 shows the "spread row" system complete with the point rows worked in. Note how the rows approximately follow the contour lines. The illustration is self-explanatory, showing that two, or at the most three, point rows are in between one or more long rows. When three or less point rows are all the point rows in the system, they should be placed together, about one-third of the distance below the guide row or the terrace above to the guide row or terrace below.

It is found that practically nothing is to be gained by laying off more guide rows than are desirable for guides in laying off the adjacent rows. That is, when the areas have been cut down to such a point that only reasonable judgment is required to complete the system, more guide rows are of no practical advantage. The objective is to put in enough guide rows so that the open spaces will not be too large for the easy distribution of point rows.

This system will work under most conditions. It may be found advisable, however, due to a peculiar slope in some cases, for four short rows, or for all the short rows, to be together. When this seems advisable visualize first how the rows would run on the "spread row" system in order to be sure that laying off all the rows together would be an improvement.

Advantages in the "Spread Row" System

1. Rows are on approximate contour without excessive fall or bagging.

2. This is a flexible system. A short or point row can easily be connected into an adjacent long row if excessive fall or bagging is found. This condition will usually be found at or near the end of point rows.

3. In heavier rains slight bagging is found, and is desirable, on the flatter slopes, since it helps protect the steeper and the more eroded part of the area. Surplus water will run along the water furrows of the steeper slopes before running over the tops of the rows on the flatter slopes. It will run over the tops of the rows on the flatter more protected ground before escaping over the tops of the rows on the steeper ground.

4. Ends of the rows point to the first long row above.

5. This system is not designed with the expectation that the rows will carry all of their own water to the outlet, although most of it will go along the water furrow to the outlet if the row is reasonably high and if there are no obstructions in the water furrow.

6. No rows are pointed into the terrace channel.

7. Point rows are run parallel to the adjacent long row below.

8. When there is an odd number of point rows in the system, the shorter one is the odd one when cultivating with one furrow to the row and working to the top of the slope.

It is true that more spaces are encountered in this system than in other systems now in use where narrow places in the row are necessary. This condition can be alleviated by making several of the rows adjacent to the narrow space somewhat more narrow than standard. By using this treatment, this condition will not be so noticeable.

In some cases, it will be found that there will be a few more point rows than when the rows are laid off according to present practices.

After laying off one or two areas between terraces, it will be found that the system is easily understood and is not difficult to execute. For best results, however, this work could hardly be entrusted to cheap or careless labor.

CONTROL OF SOIL DRIFTING IN CANADIAN WEST

By A. H. Joel [1]

FOR several decades wind erosion has been a serious problem in that part of the Canadian West which lies at the northern extremity of the Great Plains. During recent years of severe droughts this type of erosion, called "soil drifting" in Canada, has become an issue of national concern, with the result that a highly interesting and energetic control program is now under way. A brief résumé of observations made while in Canada last June may give some idea of the methods employed in the program as set up by the Prairie Farms Rehabilitation Act.

Wind erosion in the Canadian Provinces occurs chiefly on extremely light or extremely heavy soils which have been summer-fallowed for spring wheat; and in recent years serious drifting has been noted on many soils of intermediate texture where summer fallowing is practiced. Control methods center largely around strip cropping, the use of trash cover, plowless fallow, and cover crops.

Strip cropping has long been practiced in certain districts of southern Alberta and today is being adopted throughout many other areas. Stripping is usually started on a field in the year when it is to be fallowed. Strips of the desired width are laid out and alternate strips are seeded to spring grain, leaving the other strips to be fallowed. Widths of strips vary with soil type and other conditions, but they are usually 10 to 20 rods wide, and on light soils may be as narrow as 5 rods.

It is recognized that in most instances strip cropping alone is not adequate for the control of soil drifting. Suitable cultural practices must be followed, particularly those designed to secure as much trash cover as is possible and to maintain the soil in a lumpy condition. "Trash cover" refers to the stubble of grain and weeds and other organic residue left anchored in the surface soil in such a manner as to prevent it from blowing away. A good trash cover is made possible by the "plowless fallow" and is very effective in checking soil blowing.

The plowless fallow is merely a summer fallow worked with such implements as the one-way disk, the rod weeder, and the duckfoot cultivator. The aim is to check weed growth—for moisture conservation—without burying the various organic residues or releasing their anchorage in the soil. A field so worked is anything but neat, but the result in crop yield more than justifies the practice. The combination of strip cropping with a good trash cover, when properly fallowed, holds great promise for wind-erosion control in western Canada.

In localities where there is a fair amount of rainfall, a late cover crop on the summer fallow provides good protection. With this method a spring grain is seeded in the late summer, preferably the same kind and variety of grain chosen for the fallowed land during the coming crop season. In favorable years the cover crops frequently make sufficient growth to permit pasturing.

A promising research program dealing primarily with wind erosion has been launched in western Canada, and it will be interesting to note its progress. The center of the program is at the Dominion Experimental Farm at Swift Current, Saskatchewan, where an excellent soils laboratory has been constructed. Many field and laboratory investigations are planned, some already under way. New types of farm implements are being developed to provide suitable methods of cultivation. One of the most interesting developments along this line is a blade-type implement designed to kill young weeds without seriously disturbing the anchorage of dead stubble.

A "wind tunnel" for laboratory studies and a "wind machine" for field studies, both in relation to wind erosion, also hold real promise. The latter machine is essentially an airplane propeller mounted for mobile field use and arranged to create strong air currents between lateral "walls" of board. The plan is to use this machine under varying conditions of soil, vegetation, etc. The "wind machine" and "wind tunnel" are considered first steps in the development of adequate apparatus for extensive studies in field and laboratory in connection with wind erosion.

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SOIL-EROSION PROBLEMS ON IRRIGATED FARM LAND

By Dana F. Kirkmire [1]

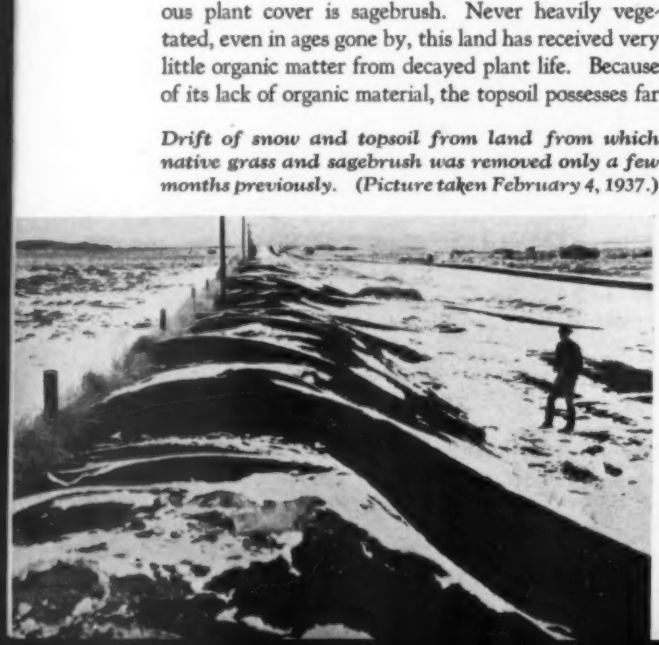
THE menace of soil erosion presents a very serious problem for the farmer on irrigated farm land. The erosion of irrigable land will never create the widespread devastation it has wrought in other localities, notably the "Dust Bowl" in the Southwest; but its effects on the individual farm may be no less acute and serious. For the most part, soil erosion caused by wind on irrigated land is a problem peculiar to a particular farm rather than to a whole section of the country. To illustrate, one farmer may have his seeding blown out of the ground two or three times in one season, while his neighbors may not experience this trouble at all because of different soil types or different cropping practices. Thus, the effects of soil blowing, as an example, may be noticeable only on a farm or two in a given area and thus not arouse much interest or publicity. But at the same time the particular farm where the blowing occurred, and others adjacent which received the deposit of soil, may be ruined.

Wind, gully, and sheet erosion all occur in varying degrees on irrigated farm land within the Shoshone Indian Reservation of Wyoming. A few of the problems encountered and means of controlling and correcting the many factors causing erosion in the particular area are described in this article.

A Land of Sparse Vegetation

Much of the land brought under irrigation by the Reclamation Service and thus made accessible to farming is ordinary arid range land, and the most conspicuous plant cover is sagebrush. Never heavily vegetated, even in ages gone by, this land has received very little organic matter from decayed plant life. Because of its lack of organic material, the topsoil possesses far less moisture-storing capacity than its texture would indicate, and the little moisture available from precipitation is used up by the vegetation it supports, or immediately runs off if the vegetative cover has been depleted. Thus, when the sagebrush and native grass cover is removed by the farmer preparatory to seeding his first crop under irrigation, the soil lies ready to be moved by the wind. The same is true also following the harvest of clean-tilled crops such as sugar beets and beans.

Drift of snow and topsoil from land from which native grass and sagebrush was removed only a few months previously. (Picture taken February 4, 1937.)



Prevent Blowing

To prevent the removal of the topsoil by the wind, the Soil Conservation Service has found that native vegetation should not be disturbed until just prior to seeding time, usually in the spring. Windbreaks along the windward sides of fields subject to blowing are recommended with a view to longtime protection. The windbreaks now being established consist of 3 to 5 rows of trees spaced 6 feet apart in the rows. The species of trees are mainly Russian olive, Chinese elm, green ash, honey locust, box elder, and caragana. It is highly probable that were sufficient tree windbreaks established on all the farms needing them, their cumulative effect in years to come would greatly alleviate wind erosion.

As a control measure after blowing has started, listing is a good practice. This, however, is not entirely successful, as once the soil starts moving it apparently can be stopped only by cessation of the wind. The best method of controlling wind erosion is to prevent it from starting.

Aside from the effects upon a given field of the removal of its topsoil, other serious damages result from unimpeded blowing—irrigation ditches are filled, fences are drifted over and rendered ineffective, and drifts pile up around buildings and corrals.

Faulty Irrigation and Gullying

The seriousness of gully erosion on irrigated land is generally more striking to the eye than any other type. Numerous places may be seen in any irrigated district where ditches have "broken out" and permitted the water to flow across the land below, quickly resulting in deep unsightly gashes. Faulty irrigation likewise may cause far greater but less obvious damage. Irrigation water will cut severe gullies in ditches which

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Downstream end of same gully as below. The photographer stood in the main gully, which is 20 feet deep and 50 feet wide. This gully was caused by the water spilling from the end of several main irrigation laterals.

have too great a fall since, naturally, the greater the "head" of water in the ditch the greater its erosive capacity. The same factors which apply to water in a ditch are equally applicable to water running between crop rows or even over grain or alfalfa. If the slope is steep—over 5 or 6 percent in the case of row crops—and too much water is turned on to the ground, gullies will be the result.

The most striking gullies on irrigated land, however, are those caused by so-called "waste" water. While a field is being irrigated if the amount of water which runs down across the field is not judged accurately for proper absorption by the soil the excess must run off to other ground. If it runs on to a tract of native sagebrush land with characteristic insufficient vegetation, the waste water will run together in the low places and wash gullies across the sagebrush land. Repeated irrigatings of the original field with the resultant "waste" water will keep these gullies eating back until they encroach on the crop field. Serious damage to the field and to the farm as a whole will be the consequence. The same applies if the water is "wasted" on to cropland below without water-spreading ditches and proper vegetative cover to take care of it.

Sloughing Off

The dead-ending into natural drainageways of the main irrigation ditches supplying a number of farms likewise results in severe gully bank eroison for those farms bordering on the natural drainageway. These main ditches pour a quantity of water in varying amounts down the drainageway all during the growing season, creating a live stream. The banks of the drainageway are covered with only the very meager vegetation of arid conditions, offering practically no holding protection. The result is that the water undermines the bank first on one side and when that sloughs off it shifts to the other side and undermines it with the resultant sloughing and so on. Thus a relatively small stream of water will in a very short time cause an enormous gully which continually keeps enlarging and eating away farm land. Lee Harrison, a cooperator on the Shoshone project, estimated that in 1936 he lost over an acre of crop land within a quarter of a mile along one side of such a drainageway.

Proper System to Prevent Gullying

In the Soil Conservation Service program, a proper water distribution system with a minimum of "waste" water is surveyed by the engineers and constructed by the cooperator. This compares with the installation of contour-tillage practices on farms dependent on precipitation for crop production in other projects. The distribution of irrigation water is not so simple as it seems, as careful planning is required to secure a practical and economical system. Ditches carrying water usually should not have a fall in excess of one-tenth or two-tenths foot to each 100 linear feet. Where the ditches must descend steeper slopes than the above, it is necessary to construct "drops" to prevent gullying. Subsequent spreader or "pick-up" ditches must be made at intervals varying according to slope and soil type across the field. Determining the proper intervals for these "pick-ups" or "laterals", as they are called, is one of the most important factors in laying out the irrigation system. If they are spaced too far apart, water running over the slope from the ditch above will cause gullying and sheet erosion even when the slope is only moderately steep. Also, the ground immediately below the upper ditch will become soaked excessively before the water "gets through" to the lateral below, and, in time, "seep" conditions will occur with heavy accumulations of alkali rendering the ground unproductive and entailing great expense for draining and reclamation. If the

(Continued on next page)

Upstream end of gully in native cover caused by waste water from an irrigated field above.

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"Brushing Out" the Banks of Streams. C. F. Stewart Sharpe. Vol. 2, No. 10, April 1937 issue. pp. 221–224.

Changes in Atmospheric Circulation Result in Floods. B. Holzman and K. Clarke-Hafstad. Vol. 2, No. 11, May 1937 issue. pp. 254–255, 266.

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How Main Street Became the Big Ditch. Ross Calvin. Vol. 2, No. 5, November 1936 issue. pp. 102–105.

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Reservoir Silting in the New River Watershed. Carl B. Brown and F. F. Barnes. Vol. 2, No. 5, November 1936 issue. pp. 95, 106–107.

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Silt Measurements During Potomac River Flood. Vol. 1, No. 10, May 1936 issue. p. 14.

Stock Ponds in the Great Plains Drought Area. W. C. Lowdermilk and F. F. Barnes. Vol. 2, No. 3, September 1936 issue. pp. 44–47, 58.

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Traveling Soils—An Erosion Surveyor Views the Flood Zone. Mark H. Brown. Vol. 2, No. 11, May 1937 issue. pp. 252–253, 267–268.

Utilization of Small Water Powers. H. H. Bennett. Vol. 2, No. 4, October 1936 issue. pp. 74–80.

Watershed Control in Italy. Arthur C. Ringland. Vol. 2, No. 11, May 1937 issue. pp. 251, 265–266.

Watershed Treatment and Flood Control. R. H. Davis. Vol. 2, No. 11, May 1937 issue. pp. 247–250.

Weighing the Costs of Flood Control. Walter J. Roth. Vol. 2, No. 9, March 1937 issue. pp. 201, 207.

Soil-Erosion Problems on Irrigated Farm Land

(Continued from preceding page)

"pick-ups" are too close together, the irrigating of the field becomes prohibitive in cost, to say nothing of the unproductive area of the ditches themselves. A field on which a proper irrigation system is established looks very similar to one which has been contour furrowed, as the gradient in the laterals is not noticeable to the eye.

The prevention of "sloughing off" of banks along drainageways has not yet been satisfactorily solved, and cannot be solved except by reducing the volume of the waste water which causes the gullies. Only conservative use of water will avoid the distressing damage caused by the surplus turned loose to seek a course to the sea. The irrigationist must learn the fundamental truth, that he is dealing with a destructive as well as a life-giving agent. It is possible to gage more correctly the amount of water required and thus prevent the accumulation of a surplus to destroy the neighboring landscape. The control of surplus or waste water on irrigation projects is one of the most challenging problems facing an irrigation district.

Topsoil Losses Under Faulty Irrigation

A form of sheet erosion occurs under the irrigation practice known as "flooding", and also even where the more desirable system of "corrugating" is used. The amount of sheet erosion which takes place under either of the above methods varies with the slope, texture of the soil, and, most important, the "head" or quantity of water used. Other conditions being equal, if too large a "head" is used the water carries from the irrigated field a quantity of topsoil similar to that lost after a heavy rain under unirrigated conditions. Gullies may or may not be formed, and the soil loss is only evidenced by the increasing unproductiveness of a field and the accumulations of silt on fields below. A notable example of sheet erosion occurred on the Shoshone project during 1936 when one farmer washed a whole field of his seeding down on to a field below where the crop was grown. This practice has given rise to the remark that in irrigated country a farmer often has to buy the "40" below him to get back his topsoil.

Rotation Essential

On the Shoshone project, sheet erosion in combination with wind erosion has complicated crop production on new land brought under irrigation in that, through prior depletion of the vegetative cover, as much as 75 percent of the original topsoil has been removed. Thus careful crop rotation systems must be

(Continued on p. 116)

Introduced Plants in Erosion Control

Following is a list of important introduced trees and shrubs used in erosion control. It is by no means complete but it indicates a wide range of origins, together with the principal Soil Conservation Service regions in which these plants are being used to check soil losses. The list below includes many plants which were not noted in the back-cover sketches of the March and July issues of SOIL CONSERVATION.

CONIFERS

Species	Common name	Place of origin	Used by S. C. S. in region—
Larix europa	European larch	Europe	1, 5, 11
Pinus halepensis	Aleppo pine	Europe and Asia Minor	8, 11
Pinus nigra	Austrian pine	Europe	3, 5, 7, 9, 11

HARDWOOD TREES

Acer platanoides	Norway maple	Europe and Siberia	8, 9
Eucalyptus corynocalyx	Sugar gum	Australia	10
Eucalyptus globulus	Blue gum	do	10
Eucalyptus leucoxylon	White ironbark	do	10
Eucalyptus rostrata	Creek gum	do	10
Eucalyptus rudis	Desert gum	do	10
Eucalyptus tereticornus	Slaty gum	do	10
Eucalyptus viminalis	Manna gum	do	10
Fagus sylvatica	European beech	Europe and Siberia	11
Morus alba	White mulberry	China	1, 2, 3, 4, 5, 7, 8
Prunus armeniaca	Apricot	Asia	6, 7

SHRUBS, ETC.

Alnus glutinosa	European alder	Europe	11
Artemesia abrotanum	Southernwood	do	11
Asparagus officinalis	Asparagus	do	7, 8
Calluna vulgaris	Heather	Europe and Asia Minor	11
Celastrus orbiculatus	Oriental bittersweet	Japan and China	3
Colutea arborescens	Bladder senna	Europe and Africa	8
Corylus avellana	Filbert	Europe	1, 11
Cytisus scoparius	Scotch broom	do	2, 11
Elaeagnus reflexa	Bronze elaeagnus	Japan	2
Elaeagnus umbellata	Autumn elaeagnus	China and Japan	2
Ephedra sinica	Mahuang	China	8
Iris germanica	Iris	Europe	2, 8
Lespedeza bicolor	Shrub bushcover	Japan	1, 2, 5
Lespedeza cyrtobotra	do	do	1, 2, 5
Lespedeza juncea	do	China and Siberia	1, 2, 5
Lespedeza sericea	Perennial lespedeza	China and Japan	1, 2
Ligustrum vulgare	European privet	Europe and North Africa	11
Lonicera maacki	Amur honeysuckle	Siberia and Japan	2
Lonicera morrowii	Morrow honeysuckle	Japan	7
Lonicera ruprechtiana	Manchurian honeysuckle	Manchuria	2
Lonicera tatarica	Tatarian honeysuckle	Siberia	1, 3, 5, 7, 9, 11
Lonicera xylosteum	European fly honeysuckle	Europe and Asia	2, 3
Lycium halimifolium	Matrimony vine	China	1
Rosa multiflora	Japanese rose	Japan	2
Rosa wichuriana	Wichurian rose	do	1
Rosa rugosa	Rugosa rose	Japan and China	2
Rubus parvifolius	Japanese trailing raspberry	Japan	1, 2, 3, 4, 5, 7, 8
Rubus thyrsanthus	Hamalaya blackberry	Europe	2, 4
Viburnum opulus	European cranberry	do	3
Vitex agnus-castus	Chaste tree	Europe and Asia Minor	2
Zizyphus jujuba	Jujube	South Asia	6, 7, 8

BOOK REVIEWS AND ABSTRACTS

By Phoebe O'Neall Faris

MOISTURE AND FARMING IN SOUTH AFRICA. By W. R. Thompson. Johannesburg, South Africa. 1936.

A great deal of the literature which has been prepared in the United States on various conservation subjects is being carefully reviewed and adapted in South Africa. Now, in turn, investigators in this country have the opportunity to review, in Mr. Thompson's book, the preliminary studies concerning certain aspects of moisture supply and moisture dissipation in South Africa during the historic period. Aside from its wealth of data it is a thought-stimulating book and the experiments presented, although essentially South African, will be found to have an especial bearing on our problems—those of the Great Plains in particular.

It is apparent that the author, who is senior lecturer in agronomy at the University of Pretoria, has made extensive studies of the moisture conditions, present and past, of South Africa. It is apparent, also, that, in his opinion, the progressively drier aspect of his country is not due to definite climatic changes but to the greater demand for moisture and to the acceleration of run-off under modern intensive agricultural conditions. In fact, it might be said that the theme of the book is a refutation of the alleged drying up of the southern part of the African continent coupled with a defense of and a plea for soil- and water-conservation programs to fit the various regions and based on research studies and scientifically planned.

Throughout a long discussion of hydrological conditions all available information concerning moisture and its dissipation is assembled and analyzed, and voluminous references are cited as historical evidence in support of the necessity for a permanent adjustment of agriculture to natural environment.

A particularly interesting feature is the many and varied facts and theories which come to light in connection with South African climatic factors. For example, in an account of Schwartz's scheme to redivert water into the Kalahari lost lake system, the reader learns that severe droughts occurred long before the waters of the lakes were captured by the Zambesi. One is interested also to know that the Hottentot word "Karroo", applied to the arid region for many centuries, means aridity; that the Karroo flora is all very highly specialized, all plant organs being constructed either to store water or to pervent its loss through evaporation; that precipitation over South Africa is caused by world-wide atmospheric movements, not by local influences such as the Kalahari lakes. In fact, when Mr. Thompson and the reader have finished with the "Kalahari scheme", there is no doubt in the mind of the latter regarding the impractability of the much publicized plan to banish aridity from the southern part of the African continent by "restoring" the lost lake system.

Other theories which have been advanced from time to time in connection with the alleged drying up of southern Africa are discussed also. With regard to vegetal cover and moisture supply the author states that "the relation of the vegetal cover to the economic and effective utilization of rain water is undoubtedly a cardinal point in the amelioration of the drought problem in South Africa." This means, apparently, that bare spaces from deforestation, firing, and overgrazing induce evaporation from the soil and increase run-off and insipient erosion.

In a chapter presenting historic evidence regarding climatic conditions are to be found interesting accounts of irrigation farming throughout the past century, of the Bantu races with their nomadic habits, and game migrations as influenced by severe droughts and irregular, intense rain storms, of the trekking system of stock farming suitable to the climate, and of the periodical drying up of rivers throughout the past two or three centuries. In this chapter is also a section pointing out the significance of place names and Bantu expressions with regard to climatic conditions of the past.

That part of the book which deals directly with rainfall data, rainfall intensity, soil erosion and run-off, evaporation and percolation, no doubt will become an extremely valuable reference to students throughout the world who are investigating the factors affecting moisture supply and dissipation. Here all available data regarding the secular variations in South African rainfall, with their agricultural aspects, are brought together and presented in tabular form and in charts and maps. In his dicsussions accompanying the data, the author builds up vigorous and convincing arguments in favor of long-term forecasting systems to reduce losses due to periodic drought, to reduce overstocking, veld burning, and soil erosion, to increase crop production and indirectly to improve the soil iteslef. Some significant facts emerge from Mr. Thompson's description of run-off experiments conducted in 1931–35 at the Pretoria University experimental farm. The resultant data are described as unique in that they are the first of the kind to be obtained in South Africa from a properly controlled experiment. Unused veld was shown to prevent run-off and soil erosion almost entirely; Kraal-manure, when applied to maize, effected a considerable decrease in run-off (indicating the importance and effect of organic matter in run-off control); the run-off on burned veld was 27 times greater than that of a natural veld plot during a good rainfall season; Teff grass as an unusual hay crop prevents excessive erosion but permits run-off at planting time and during the establishment period; Rhodes grass used as a perrennial planted grass was most effective in preventing run-off and soil erosion; loss of water and soil respectively was 80 to 683 times greater from the uncultivated bare plot as compared with that from the veld intact plot.

Initial investigations regarding the roles of evaporation, transpiration, and percolation in the dissipation of moisture in South Africa are described in detail and the results obtained cast new light on the replenishment of the subsurface water supply and the lowering of the water table in recent years. Emphasizing the need for extensive studies along this line the author states that "all factors affecting the moisture cycle are clearly interrelated and cannot be divorced from one another. Evidently the interpretation of any one factor without due regard to the influence of the others cannot give a true perspective of the position. The need for comprehensive research in this field also cannot be over-emphasized, since, until more data . . . have accumulated, many problems will remain obscure on the moisture problem in South Africa."

The ecological, hydrological, and management aspects of veld burning, an "age-old practice in South Africa", are treated at some length, and the chapter devoted to this mooted subject constitutes a thought-provoking study. The reader who is told that "indirect evidence, collected in different parts of the country and at different periods indicates . . . that the indiscriminate burning of vegetation has led to extensive ecological changes in the flora", that "results, as far as they go, confirm the general opinion that burning is detrimental from the hydrological point of view", and that "controlled veld burning is often a necessary practice in veld management as a means of disposing of old surplus vegetation of fibrous, unpalatable character and of low feeding value" cannot but agree whole-heartedly with Mr. Thompson when he writes that "the need for further research and experimentation on veld burning cannot be over-emphasized."

This book, the result of 5 years of hard work, cannot but prove profitable reading for students of moisture dissipation and agricultural practices in the agricultural countries of the world.

Irrigated Land

(Continued from p. 114)

worked out and practiced on each farm. Row crops are being restricted and alfalfa and sweetclover are plowed under for green manure, and for many years to come rotations must be used to build up and restore fertility to the soil rather than to deplete it. The financial condition of most of the landowners makes it necessary for them to have some acreage in cash crops to meet current obligations, and at the same time necessitates careful planning on the part of the farmer, the agronomist, and the conservationist, in formulating the cropping plan.

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